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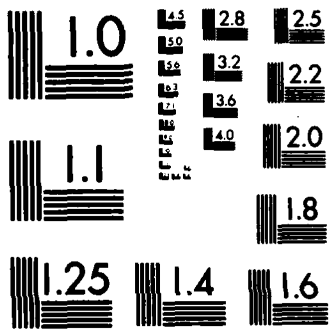

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

TAC * II AN EXPERT KNOWLEDGE BASED SYSTEM FOR TACTICAL DECISION MAKING

by

Mark J. Geschke
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June 1983

Thesis Advisor: D. R. Smith

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TAC * II
An Expert Knowledge Based System for Tactical Decision Making

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ABSTRACT

There exists a genuine need for a tactical decision making system within the Department of Defense for the small scale environment tactical decision maker. To this end, we propose TAC*II, a prototypical system for tactical decision making, to be implemented as a distributed system on micro-computers. TAC*II is a redesign and partial implementation of an expert Artificial Intelligence system proposed by previous Naval Postgraduate School students. The system receives preprocessed sensor inputs, determines what contacts are present, and suggests the best possible actions to take. It performs target analysis and correlation based on the current tactical situation. Production rules are used to discover which actions have been established by higher authority for the current tactical situation. A pattern matching algorithm provides a heuristic means of identifying similar known situations, and suggests actions to take based on those situations.

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I. INTRODUCTION

A. BACKGROUND

Years ago, military organizations were forerunners in the development of computers and computer systems, and much of the innovative research involved in those areas. For example, the founder of the COBOL programming language was Navy Captain Grace Murray Hopper. Today, the military uses computer systems for a multitude of purposes; however, private industry has become the leader in computer research. Perhaps this explains the lack of innovative and new computer systems applicable to the tactical environment in military organizations.

Since the advent of computers, decision support systems have become increasingly popular in many application areas. Originally designed for financial matters, there are virtually no areas where decision support systems have not invaded. More recently, the field of Artificial Intelligence has come to the forefront, and many of its principles can be nicely adapted to decision support systems.

We are proposing a system to fill the void in innovative tactical systems for the unit commander. The system, TAC*II, is an expert system which uses Artificial Intelligence techniques for tactical decision making. It is a redesign, expansion, and partial implementation of the system proposed by Clair and Danhof [Ref. 1].

B. PROBLEM

There are currently no expert systems in existence which support the unit commander in a tactical environment. We see this fact as an extreme shortcoming, considering the

advances which have been made recently in both hardware and software research and development. In a highly dynamic tactical environment, the major emphasis is placed on one Naval Officer, the Tactical Action Officer (TAO), and his/her memory. The TAO is required to respond to a vast amount of diverse information, received from a multitude of sources, in an extremely time critical and high pressure situation. The system which we are proposing is an automated aid to the TAO, a decision making system which will help him/her respond in a timely manner to the current situation.

Let us first examine the advantages of computer systems in the ever-changing tactical environment. The most obvious positive characteristics of computers are their enormous memory and rapid retrieval capabilities. Additionally, retrieval of information from computer memory is extremely reliable: unlike human beings, computers do not have memory lapses. Speed is another important attribute. Computers can both retrieve information from memory and perform calculations much faster and more accurately than humans.

With the above benefits of computers in the tactical environment in mind, one might ask why a decision making system designed for the tactical unit commander has not yet been developed. First, the problem may be perceived as "too difficult" for computer implementation. After all, military officers endure years of vigorous training in preparation for their role as the TAO. They often respond to situations by way of "intuition" or "gut reaction". They resolve inconsistencies or discrepancies in reports which are received through "common sense reasoning". How, then, can a computer system replace such a unique and valuable asset?

We are not suggesting that a system be designed to replace the TAO, but rather that it be utilized to enhance his/her capabilities and performance. The human attributes referred to above, "intuition" and "common sense reasoning",

are the kinds of things which Artificial Intelligence research is trying to capture in Artificial Intelligence systems. These attributes are often times programmable if enough information is available about the decision making processes of tactical commanders. The key to the success of such a system is a great wealth of knowledge, which will enable the system to emulate the TAO in most respects.

Another factor which must be considered is an increased level of risk involved in the development of tactical decision making systems. Current decision support systems deal with mundane situations like project management, financial management, and the like, where risks are generally centered around matters such as millions of dollars or personal reputation. Those risks are far outweighed by the unique risks of the tactical environment which involve the preservation of human lives. Again, we must stress that we are not suggesting a system designed to replace the TAO, although such a system could perform many of the same functions. An expert tactical system should help in the areas where its capabilities are superior; that is, memory capacity and processing speed. The final responsibility for tactical decision making still remains with the tactical commander.

The problems are not insurmountable, and neglecting the implementation of such a system would be a gross oversight. In addition to the benefits previously described, an expert tactical system has two very significant side effects. The first primary goal of military organizations is to prepare for war. Secondly, if war unfortunately occurs, the goal is to survive as the victor. An important aspect of the effectiveness of the TAO in this type of tense environment, is the ability to remain calm, and in accordance with previous training and experience, react appropriately. The commander without actual combat experience is at a marked disadvantage. Regardless of the number of training exercises in

which he/she has participated, actual combat is quite different. The chance of the TAO freezing or experiencing feelings of panic is lessened if an expert tactical system is implemented on the ship.

A second similar side effect is the inherent provision of a training tool. Junior officers would benefit from working with this type of system by observing how it correlates target information and how it makes decisions. Situations could easily be simulated, and both man and machine would try to determine the best appropriate action to take.

An expert system is needed to fill a void which currently exists in the tactical environment. Such a system's advantages are numerous whereas its disadvantages are not insurmountable. The solution to this problem is not an easy one, but it is not foreseen to be impossible. With advanced technology and new and better Artificial Intelligence techniques, the implementation of an expert tactical system should be right around the corner.

C. SOLUTION

TAC*II is our answer to the tactical problem outlined above. The system design is modelled on how the TAO is perceived to make decisions. The decision process is viewed as consisting of three phases: acquisition, analysis and decision. During the acquisition phase, the TAO accumulates information from various sources and stores that information in his memory. TAC*II's acquisition phase consists of receiving inputs from various sensors, intelligence reports, or human interfaces, and storing that information in its dynamic database. During the analysis phase, the TAO tries to determine if new information can be correlated with old information, and if so, makes a mental note of the

significance of the correlation. TAC*II performs the same function by scanning its database for possible correlating information, performing any calculations necessary in verifying correlation, and updating its database as appropriate. Finally, in the decision phase, the TAO indicates actions to take in a given situation based on current directives which should be followed, or based on similar situations which are familiar. TAC*II does the same based on the policy rules and analogous situations which are programmed into the system. These three decision phases are modelled by the three primary modules which comprise TAC*II: the World Model, which loosely corresponds to the acquisition phase; the Analysis Module, which corresponds to the analysis phase; and the Response Module, which corresponds to the decision phase.

The key to making our system "intelligent" is to fill it with appropriate knowledge. The key to coding this knowledge is, first, to find out what it consists of by discovering how the tactical decision maker arrives at his/her decisions. These decisions range from the cut and dry, where the TAO simply follows directives, to the extremely intuitive. Intuitive decisions involve the process of analogy. The TAO perceives a similarity between the current situation and some previously experienced situation. He/she recalls the successful actions taken in that previous experience, and modifies those responses to adapt to the current situation. The knowledge pertaining to the first type of decision is quite simple to incorporate in our system, whereas the second type of knowledge is much more difficult. As in most Artificial Intelligence systems, much liaison between the system programmer and the tactical expert is required to translate the decision making process into code.

The overall function of TAC*II is to take processed information from individual sensor units, correlate that information, and determine the best action to take based on programmed rules. Those actions must fulfill the requirements of higher authority, while providing the best possible chances of survival. The first and most important aspect of our system design is to allow it to react in real time. Speed is crucial because the lack of it could literally become the difference between life and death. We foresee the implementation of TAC*II as a distributed system primarily to enhance its speed. Secondarily, spreading computing resources over many microprocessors is an obvious advantage. Not only does it reduce cost, but it also adds a degree of reliability. The failure of one microprocessor does not cause the entire system to crash. Since the TAC*II system is designed as basically three separate, independent modules, we foresee a relatively easy implementation of it as a distributed system.

The second major criteria in the design of TAC*II is the adherence to the principles of software engineering. In this regard, our system would be virtually useless if it were difficult to modify. In the tactical environment, rules and situations are constantly changing, thus causing our system to also experience frequent modifications. We therefore set as a primary goal the use of modularity and modifiability principles in our system design. Not only did we desire our overall modules to be functionally independent, but additionally, all submodules and procedures should be likewise. As a secondary goal, we wanted our implemented code to be readable, and went to a great deal of effort to ensure simple things, such as common sense naming of variables, were incorporated. Our design is geared towards providing these characteristics to ensure the success of the final system implementation.

The final goal of the system design is the generic nature of the system. In its conception, TAC*II was perceived to be applicable to not only the Navy tactical environment, but additionally, to the unit commander in any of the armed services. Although we try to remain as generic as possible, in some cases we have become specialized to allow system implementation. In these cases, our primary focus is on the Navy tactical environment, although it could easily be modified to pertain to others.

Our solution to the implementation of an expert tactical system involves several assumptions. First, our system is designed from a single user perspective. Several systems currently exist, for example the World Wide Military Command and Control System (WWMCCS) and the Naval Tactical Data System (NTDS), which approach the problem at a higher level than that of the unit commander. TAC*II is geared towards the unit level of tactical command, that level which presently has no automated guidance in the decision making process.

The second assumption is that the input received by TAC*II is already processed. In other words, we will not address the issue of transforming raw data, for example, radar video, into data which is compatible with our system. Since systems currently exist which perform exactly this function, we feel that this is a valid assumption.

Finally, we assume that it is possible to obtain enough knowledge from tactical experts in order to program the heuristic similarity matching process. This may or may not be a valid assumption; however, two factors indicate that it is indeed valid. First, it is the same basic problem encountered in the development of all Artificial Intelligence expert systems. In order for a computer system to emulate a human expert, those human experts must be interviewed in depth to derive the mental processes which they go through.

If medical experts can provide enough insight into how they diagnose diseases, tactical experts can certainly provide insight into how they synthesize analogous situations. Secondly, research is already in progress in the field of Information Systems to try to determine exactly how the high level commander recognizes similarities. All which remains to be done is the coordination between researchers in Information Systems and those in tactical systems implementation, which is currently in progress.

The following chapters discuss the design and implementation of the TAC*II system. Chapter 2 presents an overall system description, while Chapters 3, 4, and 5 delve into the details of the World Model, the Analysis Module, and the Response Module, respectively. Chapter 6 summarizes our work and suggests possible areas of further research. A significant amount of code has been developed which almost completely implements TAC*II: the World Model, the Analysis Module, and one major submodule of the Response Module have been written, tested and debugged. This code is available from the authors or the thesis advisor.

II. GENERAL SYSTEM DESCRIPTION

A. ARTIFICIAL INTELLIGENCE SYSTEMS

We will describe the TAC*II system in terms of the general design of Artificial Intelligence systems, as shown in Figure 2.1. An Artificial Intelligence system is basically composed of two major parts; the Knowledge Base and the Reasoning Engine. The Knowledge Base contains information about the "world" or the environment. It is comprised of a static database which contains general information and rarely changes, and a dynamic database which contains rapidly changing information about the "world". The Reasoning Engine is the workhorse of the system. It obtains symbolic descriptions of the sensed environment through the interpreter, requests relevant knowledge from and transmits updates to the Knowledge Base, and generates symbolic descriptions of appropriate actions to be taken.

The TAC*II system is designed to perform the analysis of an individual unit's tactical situation, and to provide the appropriate response which is directed by higher authority in their promulgated policies and doctrine. Additionally, it is designed to provide heuristically derived decisions about actions to take, which are above and beyond those required by directives, and are based on the tactical situations of history. The system receives contact information which is already processed (versus raw sensor input), and, whenever possible, infers other information about the contact. It inserts this information into the World Model and performs target correlation with all known contacts. It then searches for any applicable policy rules which govern the current tactical situation, and displays the appropriate

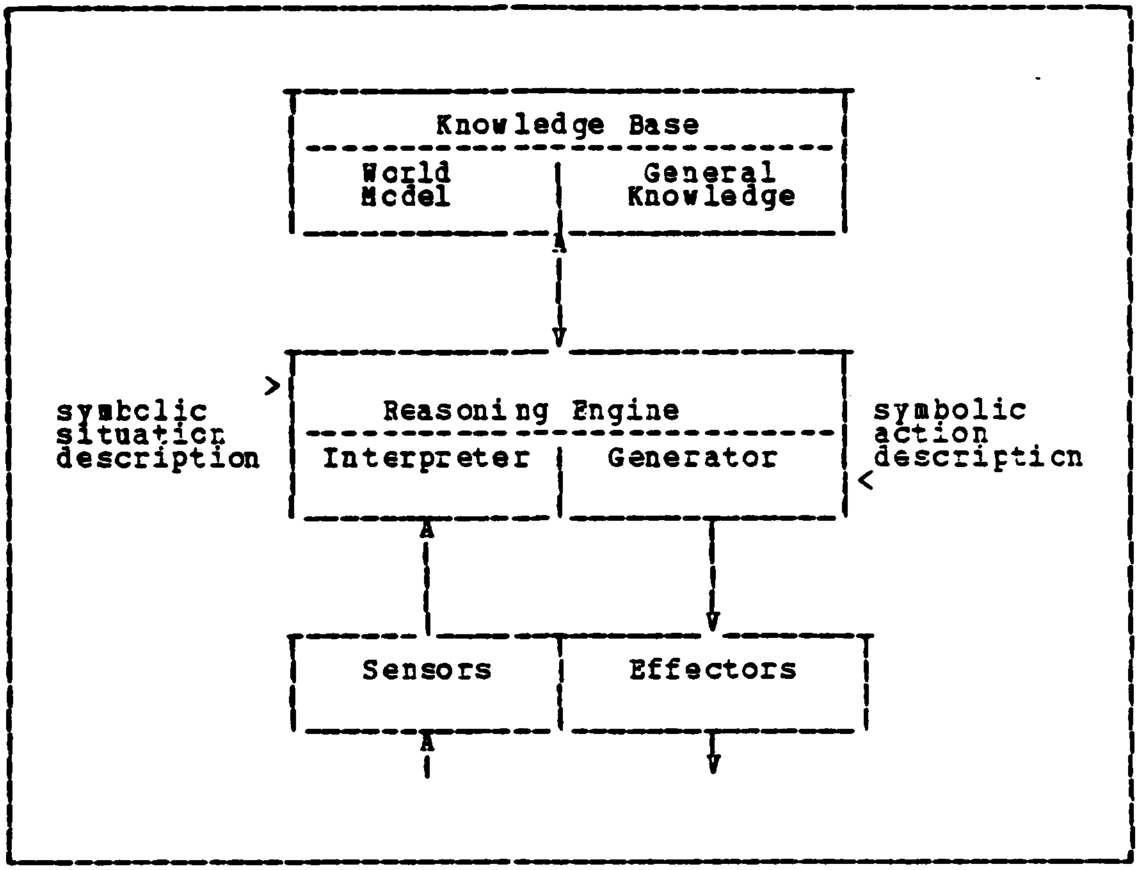


Figure 2.1 AI System.

actions to be taken on the operator console. It also searches for similar situations stored in memory, and if the search is successful, displays the associated responses on the operator console.

B. TAC*II AS AN ARTIFICIAL INTELLIGENCE SYSTEM

In the TAC*II system, the Knowledge Base is comprised of the World Model, which is one of the three primary modules, the Combat Unit Data Base, which is a part of the Analysis Module, and the production rules and patterns, which are part of the Response Module. The World Model contains a "picture" of the "world" by maintaining a dynamic database

of known contact information. It contains those aspects of the "world" which are relevant to the tactical situation and are of a volatile nature. It provides information needed by the Analysis Module and the Response Module by responding to queries transmitted to it. The World Model keeps itself current by updating its contact reports as instructed by the Analysis Module, pruning unessential archival information, and performing dead reckoning on the contact reports in its database. Dead reckoning is the method used to estimate the new position of a contact after an elapsed period of time. The World Model additionally maintains a separate archival storage structure of non-current information, leaving only the most current contact information in the primary memory structure. The World Model is organized and structured to permit easy and rapid data retrieval and manipulation.

The Combat Unit Data Base, the second part of the Knowledge Base, is a static database which exists within the Analysis Module. The knowledge which it contains is information about individual combat units. This information is used to fill in the details about contacts which are reported. It allows the system to make inferences about the possible identification of combat units.

The last section of the Knowledge Base includes the production rules and patterns. The production rules incorporate knowledge about tactical actions which are dictated by higher authority. Patterns represent knowledge about historical battle scenarios or war gaming experiences. Associated with the patterns are actions which represent knowledge about what has been or could be done in a given situation.

The Reasoning Engine is comprised of the Analysis Module minus the Combat Unit Data Base, and the Response Module control mechanism. The primary job of the Analysis Module is to conduct the analysis and correlation of contact information received, and to induce as much information as

possible, until a high confidence classification level of each contact is made. It receives preprocessed, single sensor inputs, and through searching the Combat Unit Data Base, determines what additional unit information can be inferred based on the sensor inputs. It then queries the World Model for similar contacts, and performs target correlation between the current contact and those received from the World Model. If a positive correlation is made, the Analysis Module transmits the updated information to the World Model, including any "uncorrelations" when required. In addition to transmitting new contact information to the World Model, it sends contact updates to the Response Module to trigger a search for appropriate responses to the new situation, and transmits target analysis and correlation information to the operator console. Finally, it provides an interactive query mechanism to the console operator for obtaining both static information from the Contact Unit Data Base, and dynamic information from the World Model.

The Response Module portion of the Reasoning Engine has the primary function of determining appropriate responses given a new instance of the "world". It receives a contact report from the Analysis Module and searches two separate structures for similar situations. First, the Response Module searches through its production rules, which represent concrete tactical knowledge of current directives and policies. For all rules which match the current situation, the associated responses are transmitted to the operator console. Next, it searches through its memory of programmed historical situations for those which are similar to the current situation. For those situations which match, their associated responses are modified to apply to the current situation, and summarily transmitted to the operator console.

C. INPUT

TAC*II's three primary modules are functionally independent and designed to be implemented as parallel processes on multiple microcomputers. Sensor input to the system is of several different types. Radar data provides bearing, range, course and speed information pertaining to contacts. Electronic Support Measures (ESM) input provides bearing and emitter identification information. ESM is a passive device which receives electromagnetic radiation from other units, and determines the frequency of the emitter and the bearing of the contact using it. Sonar data provides bearing, range, depth, course and speed of contacts, as well as any possible classifications. The system is designed to receive visual reports from lookouts through a formatting device, and general intelligence reports which are received via the Naval Telecommunication System (NTS).

All of the above sensor input is assumed to be preprocessed versus raw data. Other units with processing capabilities are required to be connected to the TAC*II system. In the case of radars and sonars, these processing units will receive the raw sensor data and perform track correlation by following individual contacts along their paths. Track numbers are assigned by each of the processors to the contacts being tracked. These track numbers are later translated into new track numbers internal to the TAC*II system. This preprocessing of information could be done manually, and then input into a "smart" front-end processor which would perform interactive prompting of the user. There is no requirement that the reports be rapid or exactly in real time.

The manner in which the raw data is transformed into the required input formats is immaterial to the operation of the system. The only overriding assumption is that single sensor

track correlation is performed on each sensor which inputs data into the system.

D. ANALYSIS PROCESS

When the Analysis Module receives a new contact report from one of the above input devices, it scans its record of contacts to determine if the contact has previously been seen. If the contact has not previously been seen, it must scan its Combat Unit Data Base to try to derive additional details regarding the contact.

The heart of the Analysis Module is target analysis and correlation. When a contact report is received, the Analysis Module formulates a query of a specified format for the World Model to obtain all previous contact reports which could possibly correlate with the current report. The World Model then scans its database searching for records which meet the constraints of the query, and transmits a copy of each "matching" record back to the Analysis Module.

The Analysis Module now has the new contact report together with all similar previous contact reports retrieved from the World Model. It then compares the previous reports, one by one, with the current contact, trying to determine if they could be the same target. Backtracking is the primary method used. In this method, the positional information of the previous contact reports are adjusted to remove the effect of own ship's motion during the elapsed timeframe. If two targets are positively correlated in this manner, the strength of that correlation is derived. This correlation factor is then used to infer further information about one contact from the other. The updated reports are subsequently transmitted to the World Model.

Uncorrelation is another facet of the Analysis Module. If two contacts are correlated by the above method, and further information is received which proves this correlation to be incorrect, the process must be "undone". The contacts must be reestablished as individual contacts by appropriately making updates to and modifications of their contact reports in the World Model.

In addition to performing target correlation and analysis, and updating the World Model, the Analysis Module must also transmit contact reports which it receives to the Response Module. The Response Module, in turn, uses this updated instance of the "world" to determine if there are any rules, governed by higher authority, which are applicable in the current situation. It first retrieves the appropriate set of production rules based on the current situational readiness state. It then searches the left hand sides of this production rule set for possible matches. A match occurs if all conditions contained in the left hand side of a rule are either known to be true or unknown. To resolve those unknown conditions, the World Model is queried and responds with a yes/no answer. When rules are found to match the current situation, their right hand sides are executed, causing the corresponding action to be transmitted to the operator console.

The Response Module then determines if any historical situations stored in memory match the current situation. These historical situations are symbolic descriptions of tactical scenarios which have suggested actions associated with them. Again, the World Model is queried, when necessary, to determine specific details about certain contacts. If patterns are found to match the current situation, the corresponding actions associated with those patterns are modified to adapt to the new situation, and are then sent to the operator. Since these are heuristic types of decisions,

certainty factors are calculated to indicate how similar the current situation is to the known situation, and these certainty factors are displayed along with the proposed solution.

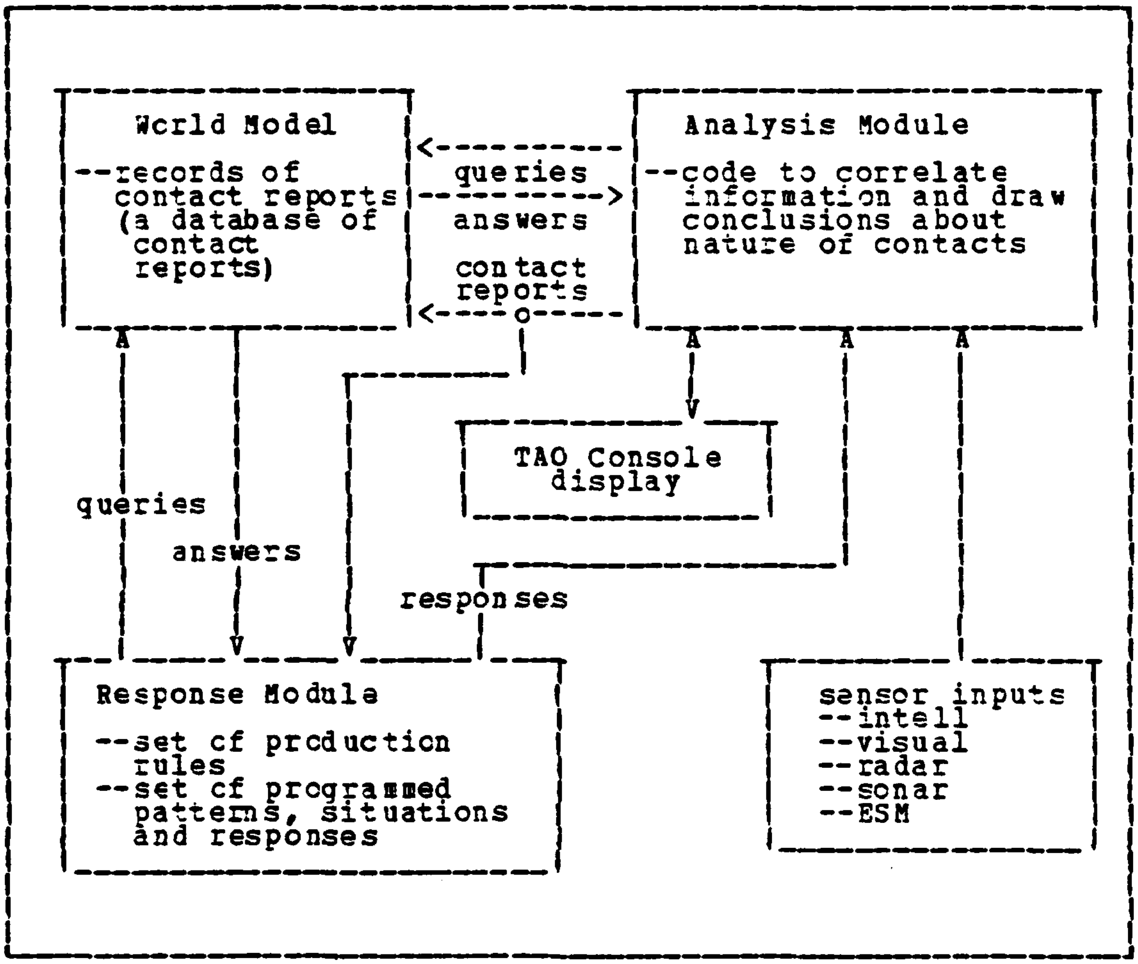


Figure 2.2 TAC*II System.

Figure 2.2 presents a general description of each of TAC*II's three primary modules together with the interfaces between each of the modules.

E. OUTPUT

The output from TAC*II is viewed as consisting of two types: internal and external outputs. The internal output is comprised of the information which the system learns and transmits to other modules within the system itself. For example, when a contact report is received, the Combat Unit Data Base is searched to determine if additional information about that contact can be inferred. The output is the more complete contact report which is transmitted to the World Model. For the case when target correlation is performed, the system determines if two separate contact reports could actually represent the same target. The system learns about the true state of the "world", and transmits this information back to the World Model. In each of these instances, output is from the Analysis Module to the World Model. This output enables the World Model to obtain a more accurate snapshot of the "world" by keeping as current as possible on the state of the "world".

External output is that which is generated by the TAC*II system for display on the operator console. During the target analysis and correlation phase, the analysis information is displayed on the operator console. Outputs are also displayed at the console from the Response Module. The first type consists of actions to take based on the current situation, and governed by the policies of higher authority. The second type consists of both actions to take based on the similarity of the current situation to a remembered situation, and their associated certainty factors.

F. EXAMPLE

In order to clarify the total process in action, we present an example and step through the various phases which TAC*II would execute. We begin with the assumption that cur

ship is steaming independently, and that as of yet, no contact reports have been received. An input is then received from the processor which handles ESM contacts. The ESM processor is assumed to translate the frequency into the type of emitter which generated the signal, and to transmit a properly formatted contact report to the Analysis Module. Once the Analysis Module receives this report, it searches its Combat Unit Data Base for all vessels which are equipped with that particular type of emitter, and inserts that information into the contact report.

Now the Analysis Module tries to perform target correlation. The contact report is placed on a queue, and a query is formulated based on the bearing of the contact. The query is transmitted to the World Model, which, in turn, tries to "match" up the query to entries in its database of contact reports. In this case, since no other contacts have been previously encountered, the World Model returns only the original contact report to the Analysis Module. The Analysis Module then simply transmits the contact report from the queue to the World Model in order to update its picture of the "world".

The contact report is additionally transmitted to the Response Module. The Response Module checks its production rules to determine if there is any policy governing this particular situation which must be followed. It formats queries to the World Model if it needs additional information about the current situation. If rules are found which match the current situation, the actions represented by the right hand sides of those rules are executed and displayed on the operator console. The Response Module also checks its store of remembered situations for similar patterns. If any are found to match, it again formats queries to the World Model to obtain specific details. The actions corresponding to remembered matching situations are then adapted to the current situation and passed to the operator.

We now receive an input from the processor which handles surface radar contacts. The contact report from this processor will include the bearing, range, course and speed of the contact. The same process is involved as delineated above. To initiate the target correlation procedure, the Analysis Module formulates an appropriate query to the World Model. In this example, the World Model will respond with the ESM contact. The Analysis Module now has the current contact report and the previous contact report, and tries to correlate the two. The method used is a form of back-tracking. The positional information of the first contact is adjusted to account for the relative motion of own ship during the elapsed time between the two contact reports. A calculation is performed to determine what course and speed would have been required for the first contact to get to the position of the second contact. The proximity of the required course and speed to the actual course and speed determines the believability of the correlation, called the confidence factor. At this point, the knowledge gained is incorporated into each of the contact reports, which are then transmitted as an update to the World Model. In the case of an "exact" correlation, the two records would be merged prior to transmission to the World Model. Finally, the Analysis Module transmits its information to the Response Module, which proceeds to search for applicable rules and similar remembered patterns, as outlined above.

III. WORLD MODEL

A. GENERAL DESCRIPTION

The World Model is a dynamic knowledge base which contains specific facts about the "world". It contains those aspects of the "world" which are relevant to the tactical situation, specifically, up-to-date contact reports of currently active contacts. Inputs are received by the various sensors, whose associated processors transform the raw data into a compatible format and perform track correlation. The resulting contact reports are transmitted to and processed by the Analysis Module, and are subsequently stored in the World Model. In short, the World Model is a contact informational database; however, this module additionally performs many database management system functions.

The World Model interfaces with both the Analysis Module and the Response Module. Both of these modules require that a query service be provided for the contact reports which are known to the system. The World Model performs this service. In the case of the Response Module, the queries will be requests to determine if a contact with certain specifications exists. These queries will require a boolean type response. The Analysis Module queries are requests for all contact reports which meet certain specifications. They therefore require a more complicated response. Specifically, the World Model response to the Analysis Module is a list of contact reports which meet the specified requirements.

The World Model must also be able to add and delete contact reports, as well as update contact reports under the direction of the the Analysis Module. The addition and

deletion of contact reports are handled much like the standard database operations. The updating of contact reports is similar to the update database operation. However, the old information stored in the contact report is saved in archival storage.

Another function of the World Model is the dead reckoning of old contact information. Since contact data is time sensitive, we must update old contact reports to keep the tactical situation as current as possible. The technique for estimating the possible position of the contact is called dead reckoning.

The basic principle of dead reckoning is to project the position of the unit along its last known course and speed for the time interval since the last known position. A modification of this technique is to project the contact towards own ship, assuming that the contact will be travelling at its maximum speed. This modification is used by the World Model, and yields the closest possible position of the contact. This is a "worst-case" analysis approach to the dead reckoning problem, and is a heuristic versus algorithmic technique.

B. DETAILED DESCRIPTION

1. Database Structure

The knowledge contained in the World Model is of three types: current knowledge about active contacts, historical knowledge about active contacts, and knowledge about the estimated position of active contacts. The current and estimated position knowledge resides in primary memory. These two types of information are the most frequently accessed. A dynamic structure is utilized to handle this information, taking advantage of the access speed increases that are available from using structures of this type.

It is important to remember that the World Model is a contact informational database and performs several functions of a database management system. This implementation is just one of the ways in which the World Model might be structured. It is envisioned that further research coupled with innovative database management systems could serve to improve the performance of the World Model with respect to real time calculations and responses.

The three types of knowledge mentioned above have three separate structures. The current knowledge about active contacts is organized in a three dimensional binary search tree. Two other schemes, a relational model and hashing, were considered during the design phase. The contact data does not readily lend itself to storage in a relational manner, and hashing is very sensitive to collisions and bunching of information. Thus, these two schemes were discarded in favor of the three dimensional binary search tree. It was decided that the most utilized fields for access were the track number, the bearing, and the distance of the contact. This implementation is a single tree with the equivalent of three binary search trees woven through it, all using the same contact report nodes. The three inter-threaded trees are based on the three primary fields, track number, bearing and distance. This structure allows for rapid access for the primary fields, and it saves storage space since the trees use one set of contact report nodes. If a query from the Response Module or the Analysis Module requires that other fields be accessed, an ordinary inorder search of the database is performed.

The second data structure in the World Model, archival storage, holds the historical knowledge about active contacts. It is anticipated that in the final production model, archival storage will reside on a secondary storage device. In the current prototype, archival

storage is kept in a separate data structure in primary memory. This data structure is a linked list of linked

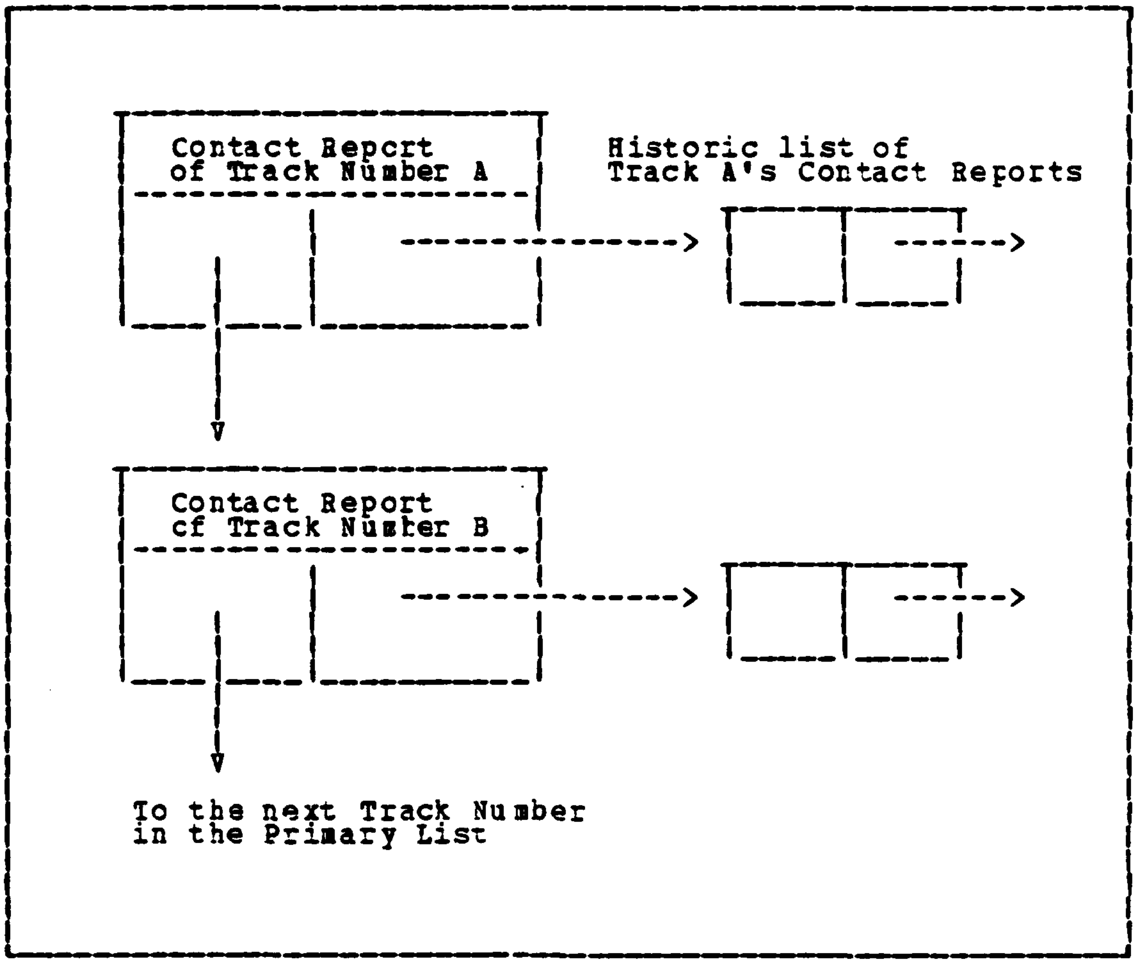


Figure 3.1 Archival Lists.

lists, as shown in Figure 3.1. Each node in the primary list is composed of a contact report of a specific track number and two pointers. One pointer points to the history list for that specific contact, essentially a linked list of old contact reports. The other pointer points to another contact report's history list. Access of information in archival storage is performed in unsorted, linear fashion.

This method is not optimum with respect to access times; however, the archival information is infrequently utilized. Thus, the time required for retrieving information from archival storage has a negligible effect on overall system performance.

The third data structure is the organization of knowledge about the estimated position of active contacts. This structure is known as the Dead Reckoning(DR) List and resides in primary memory. The DR List is a linked list of an abbreviated version of the full contact report. This record structure contains the contact's track number, date time group, position report, which in this case is the DR position, and a pointer to the next contact's DR record. The decision for using this shortened version of the full contact report was based on better memory utilization and the fact that DR reports were estimated positions. If detail is desired, the full contact report can be easily retrieved.

2. Contact Report Structure

The contact report, as shown in Figures 3.2 and 3.3, is the data structure that holds all relevant knowledge about an active contact. The basic characteristics of any contact are track number, date time group, and position. Track number is used as a locator for the contact report, while the date time group and position fix a contact's position at a specific time. The rest of the contact report is a further classification of the contact obtained through analysis and inference. For example, it can be inferred from a surface radar contact that the contact is a surface or submarine platform type. From an ESM intercept, the emitter is identifiable. Additionally, the platform type, alliance, type class, units in that particular class, other emitters on the particular type class, and weapons, can be inferred.

```
 ______________________________
| Track Number                 |
|------------------------------|
| Date Time Group              |
|------------------------------|
| Position Record              |
|------------------------------|
| Ident Record                 |
|  ___________________________ |______
| |  Platform Type            |    ---|---> Platform Records
| |  Platform Confidence      |       |
| |---------------------------|------ |
| |  Alliance                 |    ---|---> Alliance Records
| |  Alliance Confidence      |       |
| |---------------------------|------ |
| |  Type Class               |    ---|---> Class Records
| |  Class Confidence         |       |
| |---------------------------|------ |
| |  Unit Name                |    ---|---> Unit Records
| |  Unit Confidence          |       |
| |___________________________|______ |
|------------------------------|------
| Emitter                      |    ---|---> Emitter Records
| Emitter Confidence           |       |
|------------------------------|------ |
| Weapon Record                |    ---|---> Weapons Records
|------------------------------|------ |
| Correlated Track Number      |    ---|--> Correlated Records
| Correlation Confidence       |       |
|______________________________|______|
```

Figure 3.2 Contact Report.

The final field of the contact report, the correlation record, also requires elaboration. It is a list of track numbers that have been correlated to the contact report to which it is attached. This correlation record serves to store extra knowledge about the reasoning that took place in performing target classification and identification. This analysis and inference is performed by the Analysis Module which is described in the next chapter. However, it can be seen that the contact report serves to store both object knowledge about the contact, basically positional information, and analytical and inferred

knowledge. These record attributes were developed with respect to the functioning of the Analysis and Response Modules, and the types of information that they require to be associated with each contact report.

In addition to the above information, confidence factors are attached to most of the fields of each contact

```
Bearing
Range
Elevation
Position Confidence
Course
Speed
Max Speed
```

a. Position Record fields

```
Weapon Type
Weapon Name
Weapon Confidence
Up Status      (percent)
In Range       (boolean)
```

b. Weapon Record fields

Figure 3.3 Position and Weapon Record Fields.

report. Since the information might have been obtained by inference or from an unreliable sensor source, these confidence factors indicate to the operator the reliability of the information, since the information might The Analysis Module will fill in these confidence factors during its processing of the original sensor data and during contact report correlation.

A final comment about the structure of the contact report is necessary due to the manner in which the Analysis and Response Modules operate. One will note from Figures 3.2 and 3.3, that all fields below the position record exist as linked lists of records. Again, due to the analytical and inferential nature of the Analysis Module, a number of possibilities may be inferred from a single piece of sensor data. For example, a certain type of radar may exist on both surface and air platforms. These platforms may have a variety of type classes such as destroyers, cruisers and others. Further analysis reveals that many units are possible underneath each type class, and other emitters and weapons are carried by these units. One can see that this contact report contains a very large amount of knowledge. These linked lists of possibilities, coupled with their respective confidence factors, will eventually lead to a concrete target identification.

C. WORLD MODEL OPERATION

The database operations of the World Model are initiated by communications from either the Analysis or Response Modules. After initial startup, the Analysis Module sends new contact reports to the World Model to add to its database. The dead reckoning mechanism checks every fifteen minutes for any contact in the database which has not been updated for a period of fifteen minutes. The dead reckoning mechanism runs continuously after the initialization of the World Model.

Once the World Model has been started up, it waits for input from either the Analysis or Response Modules. The operation that the World Model performs, based on a communication from the Response Module, is basically to search the database to find contacts which conform to the Response

Module query. When the search is completed, a boolean-type answer is returned indicating whether or not a report was found. For instance, a query from the Response Module might be "Is own ship within the range of track 123's missiles?". (Note that this English language query will be formatted into the report query record by the Response Module.) The World Model will search the database for track number 123, look at the In Range field of the record of the specified weapon, and send back the reply to the Response Module in a format known as the Query Response.

The Analysis Module's communication to the World Model causes a variety of different operations to occur. Similar to the Response Module query, one of these operations is caused by the Analysis Module sending a query to the World Model invoking a search of the database. This search can be of the active database, or archival storage, or both. The World Model will search its database for contact reports meeting specific requirements, and send these back to the Analysis Module as a linked list. For example, in order to perform target correlation, the Analysis Module may want all contacts within a specified range of bearings. The World Model will return the linked list of contact reports that fulfill this requirement.

As previously mentioned, the Analysis Module initially starts up the World Model by sending the first contact report. This contact is received by the World Model and the database is created. The World Model's operations of addition, update, drop track, and remove track, coincide with the basic operations of add, update, and delete, performed on a typical database.

The update operation is caused when the Analysis Module is sent a sensor report which changes the knowledge about a known contact report. This update may be caused by a change in positional information (i.e., a change in bearing, range,

course or speed), or a change caused by analytical or inferential computations performed by the Analysis Module. In either case, the Analysis Module sends an updated version of the contact report to the World Model. The World Model then takes this updated version and places it in the database, and additionally sends the replaced contact report to archival storage.

The drop track and remove track operations are analogous to the deletion operation performed on a database. The reason why there are two operations that basically delete information from the World Model can be explained from an example of a tactical situation analysis. Suppose a contact, which has been identified, moves away from own ship, and the information on this contact becomes of minor importance to our tactical situation. If the contact is a warship, we may want to save our information in archival storage. If the contact is a merchant ship, we may want to delete all the information on the contact. The drop track operation, triggered by the Analysis Module, is simply the shifting of the contact report from the primary data structure into archival storage. The remove track operation, also triggered by the Analysis Module, is a total deletion of the contact information in both the primary data structure and archival storage.

The remaining operations of the World Model deal with the capabilities desired of a computer system in a tactical environment. The computer system in a tactical environment periodically requires preventive maintenance. It is desirable to be able to regenerate the information contained in the computer system after an inoperative period of time. To fulfill these requirements, the World Model has the capability to save the contact information in primary memory on a secondary storage device. The World Model can regenerate this information by invoking procedures which restart both

the primary data structure and archival storage. It is important to note that the restart of the World Model should be performed only when the "down time" of the system is short and the tactical picture has not significantly changed. Presumably, this decision will be made by the operator. Otherwise, if the down time is lengthy, the World Model should more properly be initialized and started anew.

IV. ANALYSIS MODULE

A. BASIC DESCRIPTION

The Analysis Module is the basic foundation of the TAC*II system. Its primary function is target identification and correlation. During its operation, it produces an analysis of own ship's tactical situation. The Analysis Module receives as input preprocessed sensor data and produces as output a target identification with associated confidence factors. These confidence factors are an indication of the certainty of the target identification. As more sensor data is received, the Analysis Module makes correlations between sensor reports, trying to achieve a more accurate target identification.

The Analysis Module performs many functions relating to target identification and correlation. When a sensor contact report is received, it assigns an internal track number to that report and maintains a listing of the sensor track number and its associated internal track number. This listing is known as the Cross Reference Table and is used by the Analysis Module for contact report identification.

The Analysis Module makes inferances about contacts reported by the sensors. In order to make these inferences, the Analysis Module uses a portion of the Knowledge Base, the Combat Unit Data Base. The Combat Unit Data Base is contained within the Analysis Module and consists of static object knowledge about specific combat units.

The Analysis Module solves a relative motion problem in order to perform a correlation between two contacts. This process is called backtracking and the problem involves a determination of a course and speed required for a contact

to move from one position to another. When compared to a contact's actual course and speed, the required course and speed serves as a measure of how good the correlation is between two contact reports.

During the processing of sensor inputs, situations occasionally occur which require the uncorrelation of contact reports. For example, when a contact report is deleted from the database, its effect on other contact reports, due to prior correlations, must be negated. This is accomplished by adjusting the confidence factors of the contact reports involved, using stored information concerning the prior correlations.

Another function of the Analysis Module is to process external input and output for the system. It performs interaction with the operator console, transmitting output information and receiving operator queries.

The Analysis Module interfaces with both the World Model and the Response Module. It transmits contact report updates, additions and deletions, to the World Model, in addition to queries. It sends contact reports to the Response Module to trigger its operations. In turn, the Analysis Module receives query responses from the World Model, and action responses from the Response Module for subsequent transmission to the operator console.

The Analysis Module uses word descriptions to describe degrees of confidence in the validity of information received. Many current approaches to the implementing of certainty factors use numerics for degrees of belief. Because the Analysis Module uses inference and correlation techniques for target identification, reasoning and inferences with certainty factors is an important facet of its operation. Since reasoning with numerics proves to be restrictive in some instances, the word description sequence of Figure 4.1 was used.

Confirmed	highest confidence
Certain	
Positive	
Sure	
Confident	
Probable	
Plausible	
Possible	lowest confidence
None	

Figure 4.1 Word Descriptions.

B. DETAILED DESCRIPTION

1. Interfaces

The Analysis Module interfaces with the World Model, the Response Module and the operator console. The information flow to and from the World Model consists of database operations and queries. The Analysis Module transmits contact reports for additions and updates of the database, and it sends messages to the World Model specifying a certain contact for deletion. In order to obtain information about the tactical situation, the Analysis Module sends queries to the World Model concerning contacts, and receives the associated query responses which are lists of contact reports.

In its interface with the Response Module, the Analysis Module transmits contact updates which trigger a search for appropriate responses. The Analysis Module receives these responses, and in turn, transmits them to the operator console for display.

In addition, the Analysis Module provides an interactive query service. The operator can query the system about current tactical information held in the World Model and combat unit knowledge held in the Combat Unit Data Base. The operator also can query the system for information concerning current policies and directives which are located in the production rule portion of the Response Module.

2. The Cross Reference Table

One of the Analysis Module's functions relating to target identification is the maintenance of an internal numbering system which is used for contact report identification. The purpose of the internal numbering system is to ensure that each contact report is uniquely identified and a sensor origin of a specified contact report can be found. The Cross Reference Table fulfills this purpose by maintaining a listing of the individual sensor track numbers, which are assigned external to the TAC*II system, and their associated internal track numbers.

The basic structure of the Cross Reference Table is a series of linked lists with each node in the list containing a sensor track number and its associated internal track number. These linked lists are organized by sensor: for each sensor there exists a corresponding linked list. The division of linked lists according to sensors allows rapid access to a sensor's contacts and aids in the determination of the sensor origin of a particular contact.

In its maintenance of the Cross Reference Table, the Analysis Module performs three basic types of operations. When a sensor input is received, the Analysis Module searches the Cross Reference Table for the sensor track number. If the sensor track number is found, then the associated internal track number is returned. If not, the Analysis Module assigns a unique internal track number, adds

this pairing to the Cross Reference Table, and returns the newly assigned internal track number. Additionally, the Analysis Module uses the Cross Reference Table to find the sensor origin of a given contact report using the internal track number as an index to the table. Finally, when a specified contact is to be deleted from the TAC*II system, the Analysis Module deletes the pairing of sensor and internal track numbers from the Cross Reference Table.

3. The Combat Unit Data Base

The Combat Unit Data Base is contained within the Analysis Module and consists of static object knowledge about combat unit characteristics and capabilities. The unit attributes which are contained in this database are class name, unit name, maximum speed, and the emitters and weapons suites. The database is composed of five linked lists: the Intell List, the Quick Emitter List, the Quick Weapon List, the Fast Unit List, and the Quick Class List. Each of these linked lists is linear and unordered.

The Intell List's records contain all of a unit's attributes, and a separate record exists for each unit loaded into the Combat Unit Data Base. (see Figure 4.2 (a)) The Quick Emitter List, the Quick Weapon List, the Quick Class List, and the Fast Unit List are inverted indices to the Intell List. (see Figure 4.2 (b) and (c)) These inverted indices allow for rapid access to the names of units associated with a particular emitter, weapon, speed or class. This precludes having to do a global search of the Intell List to infer which units might be associated with a given attribute.

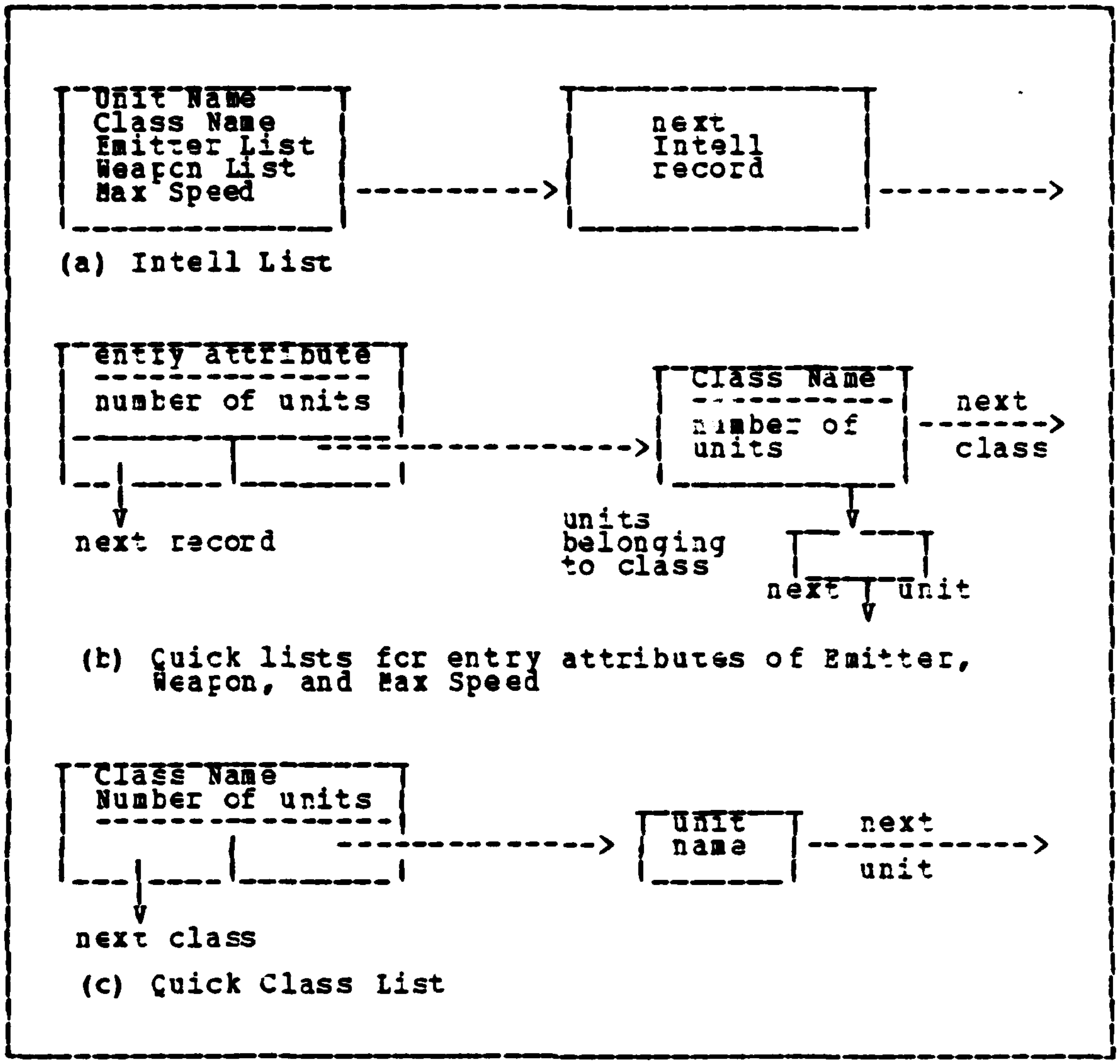


Figure 4.2 Combat Unit Data Base Lists.

4. Query Formulation

The Analysis Module formulates and transmits queries to the World Model in order to obtain additional information concerning the tactical situation. The purpose of these queries is to check the dynamic portion of the Knowledge Base for any contact reports which might provide corroborating information based on related geographical position

for target identification. The Analysis Module formulates its query based on the information contained in the temporary contact report. Specifically, the platform type, the bearing, and the range are used to prepare a query whose response will contain a complete list of all geographically related contact reports. An effort will be made to correlate these reports with the temporary contact report.

Each contact report should have an inferred platform type associated with it. The platform type has a direct effect on the bearing and range constraints of the geographical sector limits of the query. This effect is based on the inherent performance capabilities of each platform type. The encoded procedural knowledge pertaining to the bearing and range constraints incorporates the assumption that no correlation is possible outside of these geographical sector limits. Once determined, these constraints are formatted into a query and transmitted to the World Model.

5. <u>Backtracking</u>

The Analysis Module contains a backtracking procedure which solves a relative motion problem in order to make a correlation between two contact reports with different positional information. The relative motion problem is to determine the course and speed required to move from one geographic position to another during the elapsed time between two contact reports, taking into account own ship's movement. The backtracking procedure reduces the relative motion problem to a true motion problem by negating the effect of own ship's movement, and then it calculates a course and speed required for a contact to move between the two positions during the elapsed time.

The backtracking procedure consists of three parts: the calculation of a resultant course and speed for own ship during the time interval, the negation of own ship's

movement from the earlier contact report's positional information, and the calculation of the required course and speed. The calculation of own ship's resultant course and speed is performed by repeated application of the law of cosines on the various courses and speeds of own ship during the elapsed time between the two contact reports.

The next step in the backtracking procedure is to negate own ship's movement from the earlier contact report's position. This step converts the relative motion problem to a true motion problem. The earlier contact report's position is "backtracked" along a line parallel to own ship's resultant course for the distance own ship travelled at its resultant speed during the elapsed time. This results in a geographically fixed true motion problem.

The final step is to find the required course and speed necessary for the contact to travel the true distance between the two positions during the elapsed time. The required speed is a simple division of the true distance by the elapsed time, and the required course is calculated using the law of cosines. The Analysis Module later uses this required course and speed, the solution to the relative motion problem, to determine the believability of the correlation between two contact reports.

6. Correlation

The Analysis Module performs a correlation between contact reports generated by different sensors in order to ascertain additional information leading possibly to a high confidence target identification. These correlations are made by comparing two contact reports at a time. The correlation procedure generates a correlation factor given the solution to the relative motion problem, and adjusts the confidence factors within each contact report accordingly. Correlation factors describe the believability that two

contact reports represent the same target, while confidence factors describe the believability of the information contained in specific record fields.

The first part of the correlation procedure calculates a correlation factor by comparing the required course and speed with both contact reports' actual courses and speeds. The results of this comparison are translated into a correlation factor which indicates how good the correlation is between the two contact reports. A heuristic is used in this translation which pertains to the normal operations of a ship at sea. Generally, it is more common for a ship underway to make a course change than it is a speed change. Therefore the correlation is weighted accordingly.

The second part of the correlation procedure is the modifying of the confidence factors in the two contact reports in accordance with the strength of the correlation made between the two reports. A correlation between two contact reports can imply additional information about target identification, according to the strength of correlation. The confidence factors associated with each contact report will be affected in a positive or negative way. For example, if the correlation factor is high and the two reports each hold the same information in a certain record field, then the correlation should support the belief in that information. This "support effect" leads to a higher confidence factor being assigned to the information in both reports. The converse of this example is also true and results in a lower confidence factor assignment.

If on the other hand, information is held in one record and not the other, the correlation procedure transfers the information to the other contact report. The believability of this new information, the confidence factor, is then modified by the correlation factor.

7. Uncorrelation

During the processing of sensor inputs and the acquistion of more knowledge concerning the tactical picture, situations occasionally occur which require the Analysis Module to uncorrelate two contact reports. Uncorrelation is necessary in order to remove the effects of a prior correlation between the two reports.

There are three such situations that require the Analysis Module to perform uncorrelation. One situation develops when a query response for a particular temporary contact report does not include all previously correlated contact reports. For example, if Temp_contact1 had been correlated with Contact3 and the current query response does not include Contact3, then Contact3 is outside the geographical limits of the query and must therefore be uncorrelated (see Figure 4.3). The other two situations which require uncorrelation exist when a confirmed target identification is made or when a contact report is deleted from the system. For all three situations, uncorrelation negates the effect of one contact report on others in the database in order to maintain a consistent and accurate analysis of the tactical picture.

For the given situation, the uncorrelation procedure formulates a series of queries to the World Model to obtain each of the contact reports which must be uncorrelated with the temporary contact report. Each of these queries is held in a query list until the World Model responds with a query response list. As each uncorrelation is performed, an updated contact report is sent to the World Model for both contacts. The temporary contact report then replaces any copies which may exist on the query list.

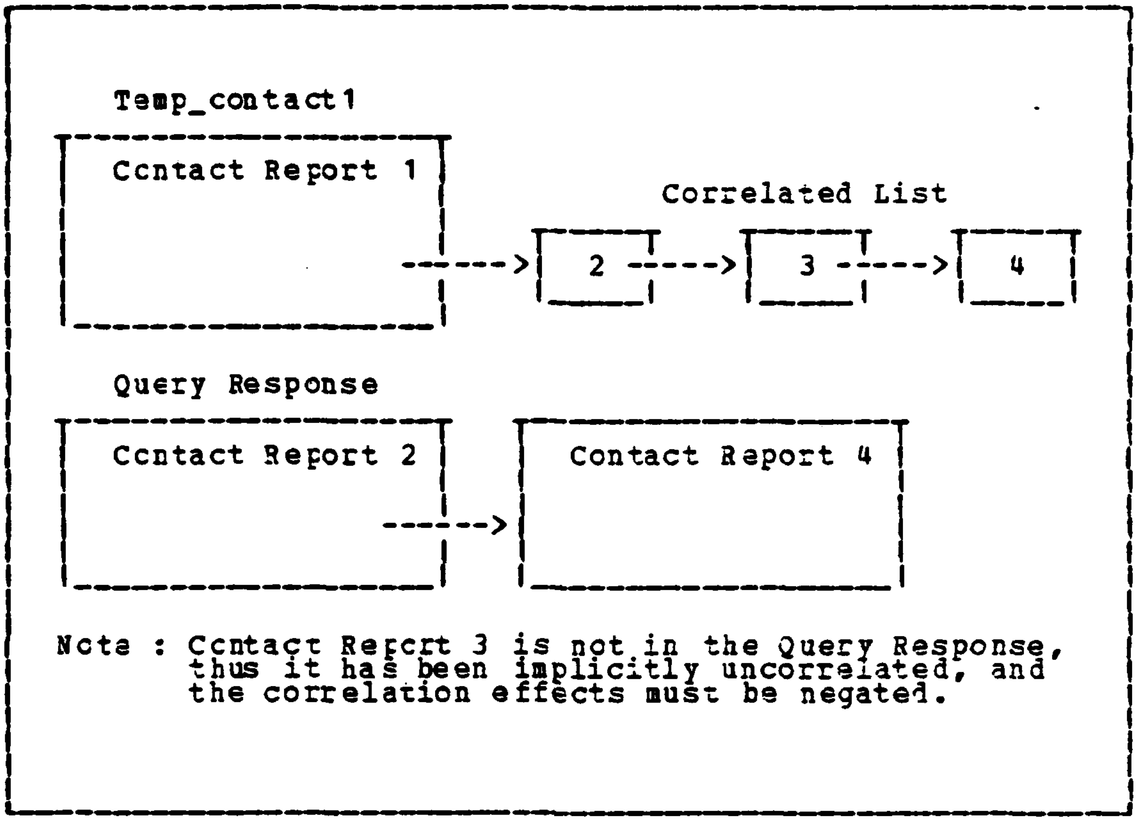


Figure 4.3 Example of Implicit Uncorrelation.

In a manner similar to that of the correlation procedure, the uncorrelation procedure modifies the confidence factors of a contact report which is being uncorrelated with the temporary contact report. As previously stated in the correlation procedure description, a correlation is generally supportive of the confidence which is assigned to knowledge contained in both contact reports. The uncorrelation procedure must remove this "support effect". In essence, the procedure performs a correlation of the two reports with an assigned correlation factor of NONE. This results in a downgrading of the confidence factors in the contact report being uncorrelated, thus removing the effects of the prior correlation. The modified

versions of the contact reports are then sent back to the World Model.

C. ANALYSIS MODULE OPERATION

1. Preliminary Phase

The Analysis Module's operation essentially begins when a preprocessed sensor input is received. This sensor input consists of positional information and a confidence factor which indicates the degree of reliability associated with the position. This information is placed into a contact report template known as the temporary contact report which is used to store the analytical and inferential knowledge about the contact's identification. This temporary contact report is ultimately transmitted to the World Model for inclusion in its database.

The first step of Analysis Module operation, after the sensor input is received, is to assign an internal track number to the temporary contact report. The Analysis Module searches the Cross Reference Table with the sensor track number. If the sensor track number is found, the associated internal track number is returned. If not, the Analysis Module assigns a unique internal track number. In either case, the internal track number is placed in the temporary contact report for report identification purposes. The next operational phase of the Analysis Module involves inferences made pertaining to possible contact identification using the Combat Unit Data Base.

2. Combat Unit Data Base

Using the information contained in the temporary contact report, the Analysis Module searches the Combat Unit Data Base for all information that could lead to the contact's identification. The amount and type of

information contained in the temporary report varies based on the sensor origin. The Analysis Module makes its inferences from the Combat Unit Data Base using the information contained in the following fields: unit name, class name, weapons, emitters, and contact's speed.

Two basic search techniques are employed based on the information contained in the above contact report fields. If the temporary contact report has a unit name with a CONFIRMED confidence factor, then the Intell List of the Combat Unit Data Base will be searched for the specific unit, and that unit's identification information will be placed in the temporary contact report. If the unit name is not CONFIRMED or the unit field is unfilled, the appropriate Class, Emitter or Weapon Quick List is searched to find all units having the given contact attributes.

If the temporary contact report does not include any information about unit name, class, emitters, or weapons, then the Fast Unit Quick List is searched, if appropriate, using the contact's speed. A check is made of the contact's actual speed against a threshold speed for applicable sensor contacts. The threshold speed for an air contact is 600 knots, and for a surface contact, it is 40 knots. If the contact's current speed does not exceed the applicable threshold speed, then a search of the Combat Unit Data Base is not performed. This precludes a search returning a majority of the database as possible target identifications, which would be of little practical use.

As the appropriate quick list is being searched, the list of associated unit names is placed in the unit list of the temporary contact report. Using the total number of units in this list, the Analysis Module calculates an appropriate confidence factor for each unit which is the probability that the contact could be that particular unit.

Next, the Intell List is searched repeatedly for each unit on the unit list of the temporary contact report. All of units' information concerning class, maximum speed, emitters, and weapons is added to the temporary contact report. At this point, the temporary contact report holds all information relating to the multiple possibilities for target identification. The fields of the report are then examined to remove all duplicate information. A count of duplicate items is kept in order to assign a confidence factor to each particular entry in the class, platform, alliance, emitter, and weapon lists. This calculated confidence factor is an indication of the believability that the contact has a particular attribute.

The inference operation of the Analysis Module, using the Combat Unit Data Base, is now completed, and the temporary contact report contains the possibilities for target identification and their associated confidence factors. This temporary contact report is then utilized to formulate a query to the World Model.

3. Query Handling

After the Analysis Module has inferred as much information about the contact as possible from the Combat Unit Data Base, a query to the World Model is formulated to obtain additional contact reports, which on the basis of their geographical positions, might provide further supportive information leading to target identification. The query is transmitted to the World Model, and the temporary contact report is placed in the query list under a unique query number.

When the Analysis Module receives the query response list from the World Model, it searches the query list for the appropriate query number and removes the temporary contact report. All contacts with a CONFIRMED target

identification will then be pruned from the query response list. Next, the Analysis Module uses the sensor origin of the temporary contact report to eliminate all contact reports of the same origin from the query response list. This elimination is possible due to the assumption that sensors perform individual track correlation in their processing of raw data. The temporary contact report and the pruned query response list are then used by the Analysis Module in the correlation phase of operation.

4. Correlation

The Analysis Module performs correlations between two contact reports in order to infer any additional information that could possibly lead to an increased confidence in target identification. The Analysis Module correlates the temporary contact report with each report in the pruned query response list, one at a time.

The first step in the correlation between the two reports involves the generation of the correlation factor. The two contact reports are passed to the backtracking procedure which solves the relative motion problem, and returns a required course and speed for a contact to travel between the two reports' positions. This required course and speed is then translated by the correlation procedure into a correlation factor indicating the degree of confidence held in the assumption that the two contact reports represent the same contact. Using the correlation factor, The Analysis Module combines the information held in the two reports and adjusts the associated confidence factors in accordance with the arrays listed in Tables I, II, III, IV, V and VI.

For an initial example to discuss how the correlation procedure uses these arrays to adjust confidence factors, we assume that the two contact reports are being

TABLE I

Support Array - Confirmed Context

Effectee

Effector	Confir	Cert	Posit	Sure	Confid	Prob	Plaus	Possib	None
Confir	Confir	Confir	Confir	Confir	Confir	Confir	Confir	Confir	Confir
Cert	Confir	Cert	Cert	Cert	Cert	Cert	Cert	Cert	Cert
Posit	Confir	Cert	Cert	Cert	Cert	Posit	Posit	Posit	Posit
Sure	Confir	Cert	Cert	Cert	Posit	Sure	Sure	Sure	Sure
Confid	Confir	Cert	Cert	Posit	Posit	Confid	Confid	Confid	Confid
Prob	Confir	Cert	Posit	Sure	Confid	Confid	Prob	Prob	Prob
Plaus	Confir	Cert	Posit	Sure	Confid	Prob	Prob	Plaus	Plaus
Poss	Confir	Cert	Posit	Sure	Confid	Prob	Plaus	Plaus	Poss
None	Confir	Cert	Posit	Sure	Confid	Prob	Plaus	Poss	None

TABLE II

Support Array - Certain Context

Effector	Effectee: Confir	Cert	Posit	Sure	Confid	Prob	Plaus	Possib	None
Confir	Confir	Cert	Cert	Cert	Posit	Sure	Confid	Prob	Plaus
Cert	Confir	Cert	Cert	Cert	Posit	Sure	Confid	Prob	Plaus
Posit	Confir	Cert	Cert	Cert	Posit	Sure	Confid	Prob	Plaus
Sure	Confir	Cert	Cert	Cert	Posit	Sure	Prob	Poss	None
Confid	Confir	Cert	Cert	Posit	Posit	Confid	Plaus	Poss	None
Prob	Confir	Cert	Posit	Sure	Confid	Confid	Plaus	Poss	None
Plaus	Confir	Cert	Posit	Sure	Confid	Prob	Plaus	Poss	None
Poss	Confir	Cert	Posit	Sure	Confid	Prob	Plaus	Poss	None
None	Confir	Cert	Posit	Sure	Confid	Prob	Plaus	Poss	None

TABLE III

Support Array - Positive Context

Effectee

Effector	Confir	Cert	Posit	Sure	Confid	Prob	Plaus	Possib	None
Confir	Confir	Cert	Cert	Cert	Posit	Sure	Prob	Poss	None
Cert	Confir	Cert	Cert	Posit	Sure	Confid	Plaus	Poss	None
Posit	Confir	Cert	Cert	Posit	Sure	Confid	Plaus	Poss	None
Sure	Confir	Cert	Posit	Posit	Sure	Confid	Plaus	Poss	None
Confid	Confir	Cert	Posit	Posit	Sure	Confid	Plaus	Poss	None
Prob	Confir	Cert	Posit	Sure	Confid	Confid	Plaus	Poss	None
Plaus	Confir	Cert	Posit	Sure	Confid	Prob	Plaus	Poss	None
Poss	Confir	Cert	Posit	Sure	Confid	Prob	Plaus	Poss	None
None	Confir	Cert	Posit	Sure	Confid	Prob	Plaus	Poss	None

TABLE IV

Support Array - Sure Context

Effector	Effectee: Confir	Cert	Posit	Sure	Confid	Prob	Plaus	Possib	None
Confir	Confir	Cert	Cert	Posit	Confid	Prob	Plaus	Poss	None
Cert	Confir	Cert	Posit	Sure	Confid	Prob	Plaus	Poss	None
Posit	Confir	Cert	Posit	Sure	Confid	Prob	Plaus	Poss	None
Sure	Confir	Cert	Posit	Sure	Confid	Prob	Plaus	Poss	None
Confid	Confir	Cert	Posit	Sure	Confid	Prob	Plaus	Poss	None
Prob	Confir	Cert	Posit	Sure	Confid	Prob	Plaus	Poss	None
Plaus	Confir	Cert	Posit	Sure	Confid	Prob	Plaus	Poss	None
Poss	Confir	Cert	Posit	Sure	Confid	Prob	Plaus	Poss	None
None	Confir	Cert	Posit	Sure	Confid	Prob	Plaus	Poss	None

TABLE V

Correlation Array

Context	Confir	Cert	Posit	Sure	Confid	Prob	Plaus	Possib	None
	Value								
Confir	Confir	Cert	Posit	Sure	Confid	Prob	Plaus	Poss	None
Cert	Cert	Cert	Posit	Confid	Prob	Plaus	Poss	Poss	None
Posit	Posit	Posit	Sure	Prob	Plaus	Plaus	Poss	Poss	None
Sure	Sure	Sure	Prob	Plaus	Plaus	Poss	Poss	Poss	None
Confid	Confid	Prob	Plaus	Plaus	Poss	Poss	Poss	Poss	None
Prob	Prob	Plaus	Poss	Poss	Poss	Poss	Poss	Poss	None
Plaus	Plaus	Poss	Poss	Poss	Poss	Poss	Poss	Poss	None
Poss	Poss	Poss	Poss	Poss	Poss	Poss	Poss	Poss	None
None	None	None	None	None	None	None	None	None	None

TABLE VI

Correction Table

<u>New Correlation Factor</u>

<u>Old CF</u>	Confir	Cert	Posit	Sure	Confid	Prob	Plaus	Possib	None
Ccnfir	0	-1	-2	-2	-3	-3	-3	-3	-3
Cert	1	0	-1	-1	-2	-2	-2	-2	-2
Posit	2	1	0	0	-1	-1	-1	-1	-1
Sure	2	1	0	0	-1	-1	-1	-1	-1
Confid	3	2	1	1	0	0	0	0	-1
Prob	3	2	1	1	0	0	0	0	-1
Plaus	3	2	1	1	0	0	0	0	-1
Poss	3	2	1	1	0	0	0	0	-1
Ncne	*	*	*	*	*	*	*	*	0

correlated the first time. The confidence factors in both reports are adjusted using the Support Array and Correlation Array as appropriate in the context given by the correlation factor.

The adjustment of the confidence factors is performed for each record field in both contact reports, item by item. Initially, the confidence factors associated with the record entries held in common by both reports are adjusted. A two pass support correlation using the Support Array is performed to mutually reinforce the information held between two contact reports which have been correlated. The temporary contact report is used as the effector in the first pass, while the query response report is used as the

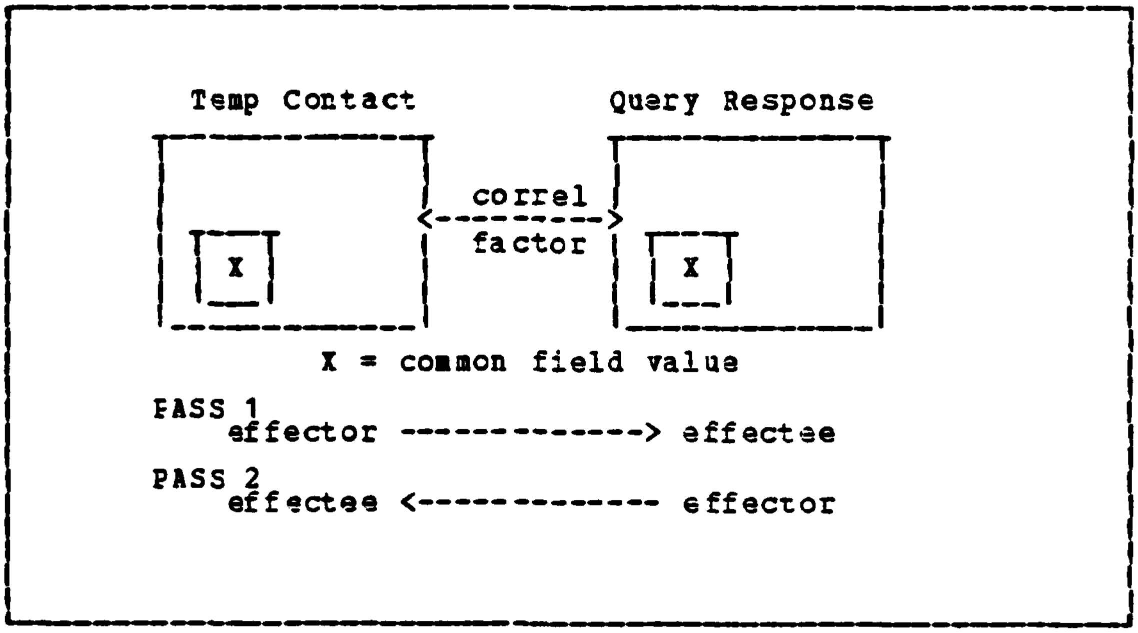


Figure 4.4 Two Pass Support Correlation.

effector in the second pass (see Figure 4.4). During each pass, the confidence factors are adjusted appropriately according to results of entry into the Support Array. After

these two passes are completed, items held in one contact report but not the other are added to the other contact report. The confidence factor assigned to this item is found by using the Correlation Array with the correlation factor as the context and the associated confidence factor as the value.

After all record fields have been processed, the correlation factor and the track number of each report are placed in the correlated list of the opposite report. At this point, the correlation between the two contact reports is completed, and the updated version of the temporary contact report is used to correlate with the next contact report in the query response list. Additionally, the updated contact report from the query response list is sent to the World Model.

For another example of the correlation procedure, assume that the temporary contact report and the second report on the query response list have been previously correlated. The old correlation factor between the two contacts is found in the correlated list of the temporary contact report. Using the new and the old correlation factors, the Correlation Correction Table is entered yielding an ordinal correction number which is applied to the confidence factors for those record items held in both reports.

Since it is possible for correlations with other reports to take place between the time one contact report is correlated with a report for the second time, there could exist record items which are in one report and not the other. These record items are added to the other report and the adjustment of the associated confidence factors are handled in the same manner as an initial correlation using the Correlation Array and the new correlation factor as the context.

When the temporary contact report has been correlated with every contact report on the query response list, the Analysis Module transmits the updated version of the temporary contact report to the World Model for storage. In addition, the Analysis Module sends the updated version of the temporary contact report to the Response Module triggering its operation.

5. Uncorrelation

An infrequent phase of the Analysis Module's operation is uncorrelation. In some situations, it is necessary to uncorrelate two contact reports in order to maintain accurate assessments of contact report identifications. For example, if a contact is deleted from the system, then the effect of that contact on all other contacts in the system should be removed. After a CONFIRMED correlation is made between a temporary contact report and a query response report, any reports on the temporary contact report's correlated list with the same sensor origin as the query response report must be uncorrelated (see Figure 4.5). This is based on our initial assumption of single sensor track correlation. Additionally, if a query response list does not include all contact reports whose track numbers are located in the temporary contact report's correlated list, then the contacts whose track numbers are not in the query response list should be uncorrelated with the temporary contact report. This situation indicates that the prior correlation is no longer valid due to the contact being outside of the geographical sector limits used for query formulation.

When one of these situations occurs, the Analysis Module transmits a query for each contact to be returned for uncorrelation. The uncorrelation operation is actually a correlation of the two contact reports with the new correlation factor being assigned the value of NONE. The old

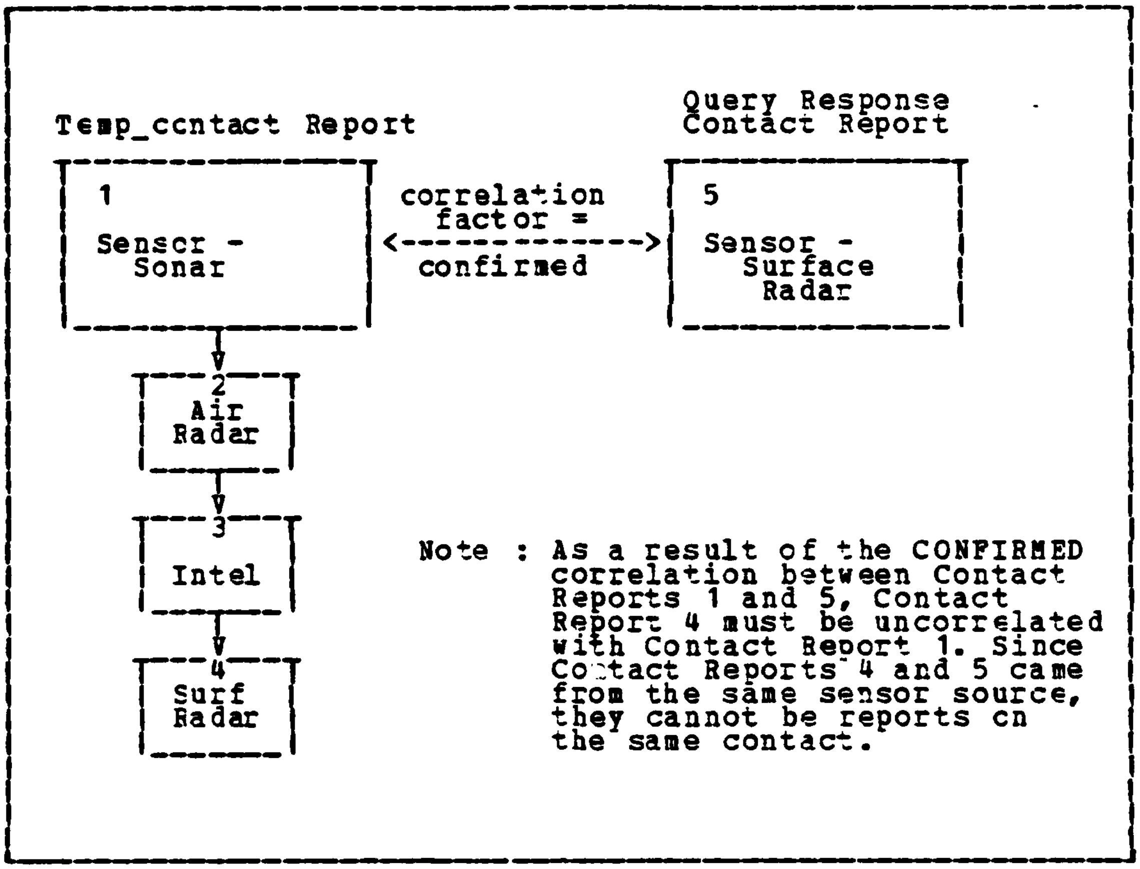


Figure 4.5 Example of CONFIRMED Uncorrelation.

correlation factor, along with the new correlation factor of NONE, is used to enter the Correlation Correction Table. A negative ordinal value is returned and applied to each record item which is held in common by both reports, thus removing the effect of the prior correlation.

When all of the uncorrelations with this temporary contact report being held on the query list are performed, the updated temporary contact report is sent to the World Model.

6. Summary

The Analysis Module performs target identification when given an input contact report. It makes inferences about target identification based on both sensor input information and correlations made between geographically related contacts. The final results of continued Analysis Module operations, when applied to all sensor inputs, is an analysis of each known contact.

D. FUTURE CONSIDERATIONS

The most important area of the Analysis Module for future research and review involves the assignment of confidence and correlation factors. These assignments are of vital importance to the accuracy and reliability of the TAC*II system output, since the confidence and correlation factors are used in reasoning and inference about possible contact identifications.

The assignment of confidence and correlation factors occurs in three areas of Analysis Module operations. First, the Analysis Module assigns confidence factors to information inferred from the Combat Unit Data Base concerning the multiple possibilities of target identification. Secondly, the Analysis Module translates the results obtained from the backtracking procedure into a correlation factor. Finally, new confidence factors are assigned to record fields in contact reports involved in a correlation based on the strength of the correlation.

In each of these three areas, a different heuristic was developed in order to assign the confidence or correlation factor by the use of several test cases and past experience. Future research and exhaustive testing should concentrate on trying to validate these heuristics. If the heuristics are not general enough, then they should be extended to produce

an accurate assignment of confidence and correlation factors.

Another area of the Analysis Module that could be enhanced through future research is the organization of data in the Combat Unit Data Base, the Cross Reference Table, and the Query List. Through the use of advanced database management techniques, access time for information retrieval could be optimized in these data structures.

Finally, in our implementation of the Analysis Module, the interactive query service for the operator was not encoded. Future work in this area should include the implementation of the interactive query service as described in the detailed description of the Analysis Module interfaces. Additionally, a new feature which allows the operator to examine the inference process that leads to a particular target identification should be incorporated. This feature would be of benefit not only in terms of increasing user confidence about TAC*II, but also in the area of system testing and validation.

V. RESPONSE MODULE

A. GENERAL DESCRIPTION

1. Purpose

The overall purpose of the Response Module is to determine whether or not a response is warranted in a given situation, and if required, which response is most appropriate. It is the most heuristic of TAC*II's three major modules since it makes a decision in an uncertain environment on how to respond to a given situation. The Response Module maintains an abstraction of the current situation and the current situational readiness state which determines the context in which the "world" should be viewed. It is triggered by an input from the Analysis Module indicating a change in either the current situation or a change of readiness state.

The action which takes place within the module is a two-phase process. First, it must be determined if there are any prescribed actions to take in the current situation based on military doctrine. Second, the current situation is examined to see if it is similar to any tactical scenarios stored in memory. If so, the successful actions taken in these scenarios are modified to be applicable to the current situation.

The output from the Response Module is a list of required actions, and a prioritized list of suggested actions to be taken together with the certainty factors associated with the matching situations. The Response Module is subdivided into two major sub-modules to handle the two phases described above: the production matcher and the pattern matcher.

2. Production Matcher

The first sub-module, the production matcher, basically handles the "black and white" rules - those which are standard military policy usually issued in directives. As the name implies, it is a set of production rules to be applied to the given situation.

Production rules are condition-action pairs written in IF-THEN format. For example, a production rule in this system might look like the following:

-IF a surface contact is detected AND it is in visual range

-THEN alert the lookouts.

The "IF" part of the productions, called the precondition, condition part, or left hand side, states the necessary conditions to be met for the rule to be applicable. The "THEN" part, called the action or right hand side, is the appropriate action to take. During execution, a production rule whose preconditions are satisfied can fire; that is, its right hand side can be executed. Production systems have the advantages of modularity, uniformity and naturalness, whereas they suffer from inefficiency and unclearness in the control flow. For further details on production systems see [Ref. 2].

The Response Module maintains the current situational readiness state. Based on this readiness state, the production rules concerning actions to be taken in that particular state are examined. The left hand sides of the rules are searched to determine which ones match the current situation based on known information. When matches are found, the Response Module queries the World Model to determine if unknown preconditions are met. For example, if a production rule states:

-IF P AND Q AND R

-THEN X

and the current situation matches P and Q, and R is unknown, then the Response Module queries the World Model to determine if precondition R is true. If R is found to be true, X is executed.

If a match is found, the right hand side of the production rule is triggered. The right hand sides incorporate the actions to be taken in a particular situation and suggest those responses to the console operator. In cases where the Response Module is triggered by a readiness state change versus a situation change, the production rules which apply in the new state must be reviewed and executed as required.

The production matcher uses forward reasoning in its search. We start from the data, the new instance of the world, and deduce the best response consistent with current directives. In other words, we search the left hand sides of production rules for matches, and the right hand sides produce the results. Backward reasoning does the opposite; it examines the right hand sides for matches and sets up the left hand sides as subgoals.

3. Pattern Matcher

The second sub-module, the pattern matcher, handles the heuristic rules. We classify as heuristic rules such things as classical tactical scenarios from the past, war gaming experiences, and similar examples together with the actions which were taken and their degree of success. These rules differ significantly from those which the production matcher handles. The production rules are concrete, they must be followed, and the commander has no choice in the matter, whereas the actions associated with patterns are basically suggestions based on previous experiences. The commander has a free choice in which actions, if any, to take. The information stored in the pattern matcher is

important because the "black and white" rules which are stored in the production matcher are not all encompassing. The "black and white" rules basically deal with the ship's readiness and rules of engagement. They are generally not tactical, whereas the rules contained in the pattern matcher are. Additionally, in a high tension environment, the ability of the pattern matcher to search through the volume of information about historical tactical experiences and relate these to the current situation could prove to be very beneficial to the tactical commander.

The pattern matcher, when given a new situation, searches its database for similar patterns based on the numbers of each platform type and their positions. Associated with each pattern are one or more situations differentiated by details such as target type, weapons capability, course or speed. The World Model is queried to determine which, if any, of the situations within the pattern, matches the current situation, and certainty factors are subsequently assigned to the matches. Finally, the actions which correspond to the matching situations are modified to apply to the current situation, and those actions are displayed on the operator console along with the situation's certainty factor.

B. PRODUCTION MATCHER

1. Details

The production matcher has not been implemented; however, the conceptual scheme for this production system is described in this section. The input to the production matcher is a new instance of the World Model triggered by a change to the "world" received from the Analysis Module. This change could be an added, deleted, or changed contact, or a change of the current situational readiness state. The

production matcher maintains the current situational readiness state which determines the context in which the "world" should be viewed. This state is viewed as a tuple consisting of various attributes. For example, the following six-tuple could be used as a state description :

<DEFCON DANGCON WARNCON WEAPSTAT RELAUTH EMCON>

where the following definitions apply:

DEFCON - the overall force defense condition

DANGCON - an internally controlled danger condition

WARNCON - warning condition normally controlled by the next higher authority in the tactical chain of command

WEAPSTAT - reflects own unit weapons status

RELAUTH - indicates whether weapons release authority has been granted

EMCON - indicates the emission condition of onboard electronic emitters

The output from the production matcher is a set of responses representing actions to be taken in prioritized order.

The first step in the production matcher algorithm is to retrieve that set of production rules appropriate to the current situational readiness state. The rules are organized by readiness states because actions required in different states are often very different. For example, the actions required in a "hot war" situation differ significantly from those actions required during "peacetime steaming". Since the number of rules associated with the different readiness states is extremely large, we envision only the applicable set of production rules being kept in short term memory. When a state change is received, the set of rules appropriate to the new state will be retrieved and any actions required in the new state will be determined.

When triggered by the Analysis Module, the production matcher scans all rules in memory and selects those which could be satisfied; that is, all condition parts of the rules must be either true or unknown. Subsequently, the World Model is queried to determine if the unknown condition parts of the retrieved rules are true. In order to perform the query, the production matcher must translate the condition part into appropriate query format which requires a yes/no answer. If all condition parts are true, either initially or after obtaining knowledge from the World Model, the rule is fired, the response is displayed, and the next production rule is checked.

The major task in the programming of the production matcher is to find the rules and to properly organize them. Additionally, the queries must be derivable from the condition parts of the production rules. Finally, actions represented by procedural knowledge must be encoded.

2. Example

The following scenario is provided to illustrate how the production matcher should operate. In this example, we start in the readiness state:

<DEFCON DANGCON WARNCON WEAPSTAT RELAUTH EMCON>
<A GREEN GREEN V NO RADIATE>

The possible values for the attributes of the tuples are listed below:

DEFCON - A, B, or C
DANGCON - GREEN, ORANGE, or BLUE
WARNCON - GREEN, ORANGE, or BLUE
WEAPSTAT - I (missiles and guns manned and ready) ...
IX (missiles and guns not operational)
RELAUTH - YES or NO
EMCON - RADIATE or SILENT

This is assumed to be the lowest normal readiness state. We will develop an escalating situation with one other combatant ship until we get to the point of weapons release. The first contact the system observes is a surface vessel. Once the contact information is received from the Analysis Module, the following rules are retrieved:

-IF a surface contact is detected AND that contact is burdened

-THEN maintain course and speed until extremis or the contact is astern

-IF a surface contact is detected AND it is not currently identified

-THEN tell the ESM operator to concentrate his search in the contact's area to obtain a classification.

-IF a surface contact is detected AND it is in visual range

-THEN alert the lookouts

The second rule in the scenario would fire for the following reasons. First, it is true that a surface contact is detected because that information was received in the contact report from the Analysis Module. Next, a query to the World Model would reveal that the contact is not currently identified. Since both condition parts are now true, the action is executed. In this case, a message would be transmitted to the ESM operator.

Now we obtain additional information which classifies the contact as an Orange Force cruiser (Orange Forces are hostile). The following rule is found to be applicable:

-IF an Orange Combatant is detected

-THEN

-Call away the intelligence collecting team

-Close the contact to obtain photographs

Since the condition part of this rule is known to be true from information received from the Analysis Module, the action is immediately fired. For this particular action, the message to call away the intelligence collecting team is displayed. Additionally, using the contact's bearing, the system will calculate and display the desired intercept course in addition to outputting the second message.

Our next piece of information received is that the Orange cruiser is tracking own ship with a fire control radar, an event that leads to the firing of a weapon. Still in the same state, we find the following rule:

-IF a hostile combatant commences tracking with a fire control radar

-THEN

-Recommend Warning Condition Orange

-Report the incident

-Shift readiness condition to

<A ORANGE GREEN V NO RADIATE>

(increase DANGCON)

When we execute this rule, the production matcher shifts the situational readiness state by changing the Danger Condition from Green to Orange. This state change causes an examination of a new set of production rules where we find the following:

-IF a hostile combatant is tracking

-THEN man the weapons systems but do not track the combatant

-IF a hostile combatant is tracking AND has trained weapons at own ship

-THEN

-Recommend Warning Condition Blue

-Shift to <A BLUE GREEN V NO RADIATE>

(increase DANGCON)

At this point, we have not yet been able to complete the manning of the weapons systems. Otherwise, we would have shifted the Weapons Status attribute. Once we have shifted to Warning Condition Blue we find the following rule:

-IF a hostile combatant is tracking own ship AND is training weapons on own ship

-THEN

-IF not at General Quarters(GQ), THEN order GQ stations

-Inform superiors of situation and intent to return fire

We now complete the manning of our weapons system and indicate this action via the operator console. This action triggers another state change to

<A BLUE GREEN I NO RADIATE>,

signifying the change of weapons status.

This limited example of some production rules demonstrates the way in which we envision the production matcher will function.

C. PATTERN MATCHER

1. Reasoning by Analogy

The original goal for implementing the pattern matching portion of the Response Module was to incorporate reasoning by analogy as the methodology by which responses would be suggested. Analogy seems to be a natural mode of thought for humans. When faced with a new situation, we usually react by searching our memory for similar situations, selecting the "best" match, and modifying the known reaction associated with the known situation to account for the differences between the known and new situations. Although recognized early and discussed in both Artificial Intelligence and Psychology circles, computer implementation

of analogical reasoning is still difficult, if not impossible, to accomplish.

The goal in this methodology is to construct a system which allows the computer to reason about one situation given a known situation which can be used as a guide in evaluating future actions or solutions. The paradigm usually associated with analogical reasoning consists of starting with a solved problem P and a corresponding solution S. To solve a new analogous problem Pa, we first must derive some analogy A: P --> Pa, then apply that "function" A to the original solution S and execute the result to obtain the solution to Pa. In the context of the TAC*II system, the goal is to first find a mapping between a known tactical situation stored in memory and the current situation, and to then apply that mapping to the "known" solution. The result will be the response to take in the current situation.

Some literature is available which discusses analogical reasoning; however, most of the literature provides only vague ideas. The geometry analogy is widely discussed, where a system is given pictures of geometric objects and is asked "A is to B as C is to which of D1, D2,...,Dn?", much like intelligence test questions [Ref. 3], [Ref. 4]. Kling [Ref. 5] proposed a system, ZORBA, which used analogical reasoning in the area of theorem proving. Moore and Newell's efforts were directed towards building MERLIN, a program capable of "understanding" Artificial Intelligence, by using a basic data structure which incorporated analogy [Ref. 6]. Winston presented a theory of analogy and a description of an implemented system which used an object oriented representation with extensible relations and both reasoned and learned through analogy [Ref. 7].

2. Applying Reasoning by Analogy to TAC*II

The overall strategy is to apply reasoning by analogy together with partial matching to the task of deriving possible actions from similar past battle scenarios. Our known patterns and solutions must be represented and stored in a knowledge base. The current situation is to be derived from information from the Analysis Module. This current situation will serve as our new situation for which the best matches are to be sought from among the known patterns. The parts of those matches which are "good enough" must then be placed into correspondence with the parts of the current situation, at which time the analogy process begins. Questions such as "Is a cruiser like a destroyer?" or "Is two ships approaching with a helicopter close by similar to two ships departing?" must be resolved. Various confidence levels will be associated with the strength of the analogies and combined to determine the most similar known battle scenarios. Finally, the differences between the two situations must be identified and resolved by appropriately modifying the known solution according to those differences.

In the problem at hand, the first consideration must be to develop a good representation of applicable knowledge in sufficient but not overpowering detail, to enable efficient partial/best matching. Since the World Model contains detailed information about each and every contact report, this knowledge base is on far too grand a scale to be of any significant value to the pattern matcher. It is mandatory that knowledge about the current situation be represented as much as possible in the same manner as the knowledge concerning the known patterns. Consequently, the information contained in the pattern matcher must be condensed and represented as a separate structure to be used in the pattern matching algorithm.

The known patterns and solutions consist of battle scenarios of the past together with the actions which were taken. With this in mind, our representation of these patterns should symbolically describe a "snapshot" of all targets, ships in our own force, and any important information about the environment (e.g., storms which would indicate low visibility or unreliable sensors, or geographical barriers such as jutting peninsulas). The known solutions will simply be represented as natural language strings with embedded variables representing specific targets, course, speed, etc. These variables will be replaced by the corresponding current targets, speed and course after the matching and analogy process is completed, and constitute the recommended course of action. These solutions constitute the procedural knowledge represented in the pattern matcher.

In order to obtain an appropriate representation for the current situation, the Response Module will receive contact reports for new, deleted or changed targets, and will internally pass them to the pattern matcher. These reports will be reformatted and stored as a "snapshot" similar to that of the known patterns. Since environmental information is not known, it must be obtained from the operator in order to place situations into correspondence.

The pattern matcher will be activated upon each receipt of a new target, a deleted target, or a changed target. It searches its knowledge base of known patterns for those which are similar by pairing up corresponding parts. Similarity is determined by importance - those high level situational parts which are specified as important in the known pattern must match exactly. Once all similar situations are discovered, the analogy process commences. In the simplest case, the current situation is an exact replica of a known pattern, and the action is simply to transmit the

known solution, with appropriate variable substitution, to the console. The most probable case, however, will be that situations are not identical. This necessitates the attempt to discover if the different situation parts could be considered similar, which in turn requires further knowledge to be stored concerning the various relationships and similarities among various information. In MERLIN's terms, we try to view situation part S1 as a different situation part S2. This process recursively proceeds until either the two parts are considered similar or not. Although the similarity question is basically all or none, the confidence levels associated with the various relationships, and the combinations thereof transform the discrete answer into a "fuzzy" one.

Once a known pattern is discovered to match the current situation, modifications must be made to the known solution in order to account for the differences between the situational parts. These modifications might be cut and dry, for instance, if the differences were simply a matter of bearing or speed, or they might be much more difficult.

D. IMPLEMENTATION

1. Introduction

The code developed for the pattern matcher does not quite satisfy the goals described above. It provides for matching the current situation with previous patterns, and assigns various confidences to the strength of the match based on bearing and range correspondences among the types of targets. The numbers of each platform type must match exactly. Once a general pattern is matched, queries are made to the World Model to determine how well specific situations associated with the general pattern match the current situation. This second match is vital to differentiate between,

for example, an aircraft carrier situation and a frigate situation, both of which would be stored under a pattern consisting of one surface contact. The matching situations are then ordered according to the confidences assigned to various components and the "best" solution, that with the highest certainty factor, is suggested as output to the console.

2. Record Structures

There are basically three record structures used in the pattern matcher, as shown in Figures 5.1, 5.2, and 5.3.

```
SIT_TARGET = RECORD
   DIFF : DEGREES; (*relative bearing difference
                   between adjacent targets*)
   TARGET_TYPE : WHAT_TARGET;(*surface, air or sub*)
   BRG : DEGREES;
   RNG : MILES;
   NEXT_SIT : SIT_PTR;(*forward pointer to next
                      target*)
   PREV_PTR : SIT_PTR;(*backward pointer*)
END
```

Figure 5.1 Situation Record.

The target record and situation record represent current targets and pattern targets respectively, while the pattern record is basically an organizer of pattern targets. A pattern is a symbolic description of a tactical scenario with most of its details suppressed. It is concerned only with platform type, bearing and range.

Associated with each pattern are various situations which are different with respect to their details. The three record types all appear in linked lists. The input current situation is a linked list of situation targets which is broken up into three doubly linked lists corre-

```
TARGET = RECORD
     DIFF : DEGREES; (*relative bearing difference
                          between adjacent targets*)
     TARGET_TYPE : WHAT_TARGET;(*surface, air or sub*)
     BEARING : DEGREES;
     RANG : MILES;
     NEXTP : TARGET_PTR;(*forward pointer to next
                            target*)
     PREV_PTR : TARGET_PTR;(*backward pointer*)
     CORRES : SIT_PTR (*link to corresponding
                           situation*)
END
```

Figure 5.2 Target Record.

```
PATTERN_LIST = RECORD
     NAME : NAME_RANGE;(*internal pattern number*)
     SUB_CASE : INTEGER;(*which situation in pattern*)
     NUM_SHIPS : INTEGER;
     SHIP_PTR : TARGET_PTR;(*pointer to list of ships*)
     NUM_SUB : INTEGER;
     SUB_PTR : TARGET_PTR;(*pointer to list of subs*)
     NUM_AIR : INTEGER;
     AIR_PTR : TARGET_PTR;(*pointer to list of air*)
     NEXT_PTR : PATTERN_PTR; (*pointer to next
                                pattern*)
END
```

Figure 5.3 Pattern Record.

sponding to ships, submarines and air contacts. The patterns are organized as a linked list of pattern records, each of which has three doubly linked lists attached which correspond to ship, submarine and air pattern targets. Additionally, a prune record, shown in Figure 5.4, is used to link those pattern records together (into a prune list) which match the current situation.

```
PRUNE_NODE = RECORD
     CONF : PERCENT;(*certainty factor for the match*)
     GOOD_PATTERN : PATTERN_PTR;(*pointer to the
                                  matching pattern
                                  node*)
     NEXT_PRUNE : PRUNED;(*pointer to next prune
                            record*)
END;
```

Figure 5.4 Prune List Record.

3. The Matching Process

The basic pattern matching algorithm consists of pruning the pattern list at several different levels. We first seek all patterns which involve the same number of platform types. From those patterns, we eliminate those whose bearings and ranges do not correspond. Finally, we determine which particular situation associated with the matching pattern is the closest match.

At the first level, the numbers of the various target platforms in the current situation are calculated. The list of patterns is then scanned for patterns which involve the same number of platforms, and only those exact matches are saved in the prune list. For example, if the current situation involves three ships and two air contacts, all of the patterns corresponding to three ships and two air contacts will be linked up in the prune list. The current situation is then reformatted to more closely reflect the structure of the patterns. Ship targets, submarine targets and air targets are segregated into separate linked lists. Relative bearing differences between adjacent targets are calculated, and the minimum differences are saved to provide a starting point for the matching process. These target linked lists are then sorted by ascending relative bearing differences.

The second level of matching involves checking both bearing differences and ranges. For each platform type, the process starts at the situation target with the minimum bearing difference, and determines if a pattern target exists within a certain tolerance of that bearing difference. If this match is successful, the two lists are traversed simultaneously to determine if the remaining bearing differences correspond. The first list traversal checks for reflection : the pattern list is traversed in the backward direction while the situation list is traversed in the forward direction. If it is discovered that the pattern does not match the current situation, the traversal is repeated, traversing both lists in the same direction to check for rotation. For the special case of exactly two targets, either reflection or rotation could provide a match. However, since reflection is tested first, it will be used unless it fails the range check.

If all bearing differences correspond through either rotation or reflection, the ranges are examined. Again, the situation and pattern lists are traversed according to whether reflection or rotation was used, to determine if the range differences fall within a certain percentage of the pattern target range. At this point, if a match is not found and there are exactly two targets, the assumed reflection-based bearing match is changed to a rotation-based bearing match. The correspondences are then reversed, and the ranges are checked again. If a pattern matches now, correspondence between parts is established by creating a link between each pattern target and its corresponding situation target. This link, the correspondence link, is used to check for correspondences among the platform types, to determine which contacts to query the World Model for, and to calculate actions.

At this point, a match indicates that the current ship targets have been placed into correspondence with the pattern ship targets, the current submarine targets with the pattern submarine targets, and the current air targets with the pattern air targets. The next level executed by the pattern matcher verifies that the relative bearings between the different target types is within the given tolerance by checking ships against submarines, ships against air contacts, and submarines against air contacts. The implementation of the inter-platform bearing match procedure consists of two nested loops. The outer loop traverses the first pattern platform list while the inner loop traverses the second. Pattern bearing differences between platform types are calculated straightforwardly, whereas the corresponding situation bearing differences are calculated after first accessing relative bearings through the correspondence link previously established. Again we have a special case. If there are exactly two targets and their ranges are similar, a reflection-based match would have been made; however, either reflection or rotation could have produced a bearing-range match. Therefore, if an inter-platform bearing match is not found at this point, the loops are executed again, reversing the correspondence links of the two targets.

We now have a prune list of all patterns which match the current situation based on relative bearing and range. If no patterns are found to match, the entire process is repeated, with less restrictive bearing and range tolerances, until either a match is found or a specified tolerance limit is reached.

The next level of the pattern matcher is highly dependent on the programming of the situations associated with given pattern scenarios and their solutions. If we have a match at this point, we have identified a general

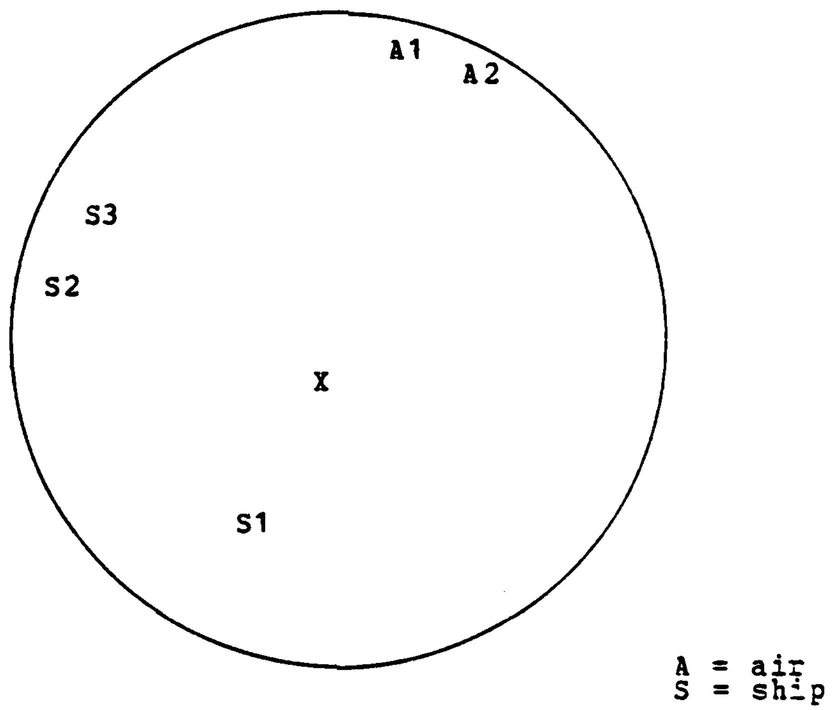
pattern which is similar to the current situation, and whose parts or targets are linked to the corresponding situation targets.

Many situations can fit any given pattern based on variables such as target type, course or weapons capabilities. For example, a pattern of one ship is a generalization of one carrier, one destroyer, etc., all of which would be handled differently. For each situation associated with a given pattern, it must be determined if the specifics of that pattern situation correspond to the current situation. The basic mechanism used is to query the World Model for specific information, such as target classification and the associated strength of that information, for each important target in the pattern. These strengths are then combined, according to the significance of each target in the pattern, and stored as a certainty factor in the prune record for subsequent sorting. Finally, the solution corresponding to the best situation matched is calculated and displayed. The console display additionally includes a description of how well the general pattern matched, and the certainty factor indicating how well the specific pattern situation matched. The opportunity is provided to view the next best matching pattern.

4. Example

An example is provided to clarify the association of situations with patterns. Pattern 7, which exists in the code and is shown in Figure 5.5, consists of three ships and two air contacts. The first situation corresponding to pattern 7 is an aircraft carrier escorted by two destroyers, and two helicopters. The second situation involves two fighter aircraft and three ships of any type. In each situation, the importance of the various parts is encoded in the algorithm. Assuming pattern 7 matches the current

situation, a series of queries are made of the World Model to fill in the details. For the first situation, the World Model is asked for the confidence that the first ship is an



Target	Bearing	Range
A1	10	100
A2	30	90
S1	200	50
S2	300	75
S3	310	75

Figure 5.5 Pattern 7.

aircraft carrier, the confidence that the other two ships are destroyers, and the confidence that both air contacts are helicopters. These confidences are weighted

proportionally according to the relative importance of that particular situation part, and combined to form a certainty factor.

In this example, since the importance of the aircraft carrier overshadows the other targets, a very high percentage of its confidence is combined with low percentages of the confidences of the remaining targets. The resulting certainty factor is a measure of how sure we are that the first pattern situation associated with pattern 7 matches the current situation.

The same process is then applied to the second pattern situation. The maximum of the certainty factors found for the two pattern situations related to pattern 7 is stored in the prune record corresponding to that pattern. Finally, the action associated with the best matching situation is calculated to apply to the current situation. In this example, the first pattern situation is determined to be the best match, and its corresponding action is to close the aircraft carrier. The link from the pattern target to the situation target provides access to the carrier's bearing, which enables the pattern matcher to calculate the appropriate course. This action is then displayed on the operator console together with its certainty factor.

5. Future Considerations

The code as implemented provides the overall structure for pattern matching; however, several enhancements would be desirable. First, the pattern matcher saves only those patterns which have the same number of platform types as the current situation. Realistically, a similarity between the current situation and a pattern may exist without this kind of match. Knowledge about similarities, embedded in this sub-module, would allow non exact matches if the differences were not significant.

The tolerances for bearing differences and ranges are presently static and are applicable to all patterns. It is conceivable that for some patterns, these tolerances need not be very strict, whereas for others, it is of the utmost importance. Each pattern could incorporate its own restrictions on bearing and range tolerances to avoid the global restrictions.

Only the best situation associated with a matching pattern is saved, and its corresponding action displayed. The operator only has the option of seeing actions associated with other matching patterns displayed after the best match is determined. Modifications could be made to additionally allow the operator to view alternative actions corresponding to a given pattern, if desired.

One example of a pattern and its corresponding situation/action pairs was encoded. Further research needs to be done to determine actual patterns to be implemented, the situations which fall under those patterns, and how to handle the associated actions.

Finally, a query mechanism to provide the operator with access to the knowledge incorporated in the Response Module is desirable. This would allow the operator to determine how actions were derived by the system from production rules in the production matcher and from the similar situations in the pattern matcher.

VI. CONCLUSION

A. OBJECTIVES AND RESULTS

The primary objective was to design in detail and implement, as much as possible, an expert system for use in the tactical environment. This goal has been achieved: the World Model and the Analysis Module have been fully implemented, and a portion of the pattern matcher within the Response Module has been implemented.

The target machine for the implementation of TAC*II is a distributed microcomputer network. Presently, TAC*II is written in Pascal/VS and runs on an IBM 370/3033AP in the VM operating system. The distributed nature of the TAC*II system is simulated through the multiuser environment of CP. The World Model and the Analysis Module run on individual instances of CMS, and communicate with each other using the virtual card punch mechanism. Although, the pattern matching portion of the Response Module has not yet been interfaced with the remainder of the system, it is also implemented in Pascal/VS on the same system.

In the tactical environment, a system like TAC*II must operate in real time. Currently, it has not been verified that TAC*II will actually meet this requirement; however, due to the system design, we believe that it is possible. Our goal was not to design a prototypical system which did run in real time, but rather to design a system which performed the required functions. Once our system is fully operational, it can be modified or optimized to meet the necessary time requirements.

TAC*II was intended to be a generic expert tactical decision making system. This objective was met as much as possible; however, our past Naval experience and the desire to complete module implementation caused a few minor deviations from this goal. Some modifications will be necessary to convert the system from the Navy tactical environment to a different tactical environment; however, the basic system structure is equally applicable to all military organizations.

The adherence to accepted software engineering principles has and will continue to benefit the users and modifiers of our system. TAC*II was designed in a modular fashion using the idea of "black boxes". Procedures were written to perform functions independently, so that once a procedure was verified, it could be treated like a "black box". The primary module communication is well defined by specific record structures. The entirety of the code was written with readability and comprehensibility in mind, and comments were generously provided.

B. FUTURE CONSIDERATIONS

As indicated in the previous section, TAC*II has not been fully implemented. With the completion of the overall system, the inclusion of "expert" knowledge, and the implementation of TAC*II in a distributed environment, the system can be fully tested.

Expert knowledge, that which is domain specific, must be obtained and placed in the Response Module. This knowledge will be implemented in two areas: the production rules, and the situation/action pairs associated with patterns. Within the production rules, military doctrine must be translated into IF-THEN rules. Within the pattern matching portion, experts must provide situations and corresponding actions to

be translated into coded procedures. In addition, expert knowledge about individual combat units will have to be obtained and placed in the Combat Unit Data Base of the Analysis Module.

One characteristic of the final production model of TAC*II will be that it operates in real time. The data organization and information retrieval methods used in TAC*II have a direct effect on system response. Future consideration should be given to the storing of information in data structures which allow more efficient and optimal search strategies to be implemented. Further research and the application of advanced database management techniques should prove beneficial in the effort to improve the system response time of TAC*II.

In the implementation of TAC*II, confidence factors play a critical role in making inferences about target identification and in matching a current situation with a pattern and its associated actions. It is of vital importance that these confidence factors reflect the true believability of a specific piece of information in order to preserve the accuracy and reliability of inferences and analogies made by the system. The heuristics used in the generation of these confidence factors should be checked against tactical expertise and experience to ensure universal acceptability. Exhaustive testing using historical and simulated battle scenarios should be performed in order to validate these initial heuristics.

The operator query mechanism which was discussed in a previous chapter is yet to be implemented. It incorporates the selected retrieval of knowledge from the World Model, the Combat Unit Data Base of the Analysis Module, and the rules of the Response Module. This could be enhanced to incorporate a knowledge tracing mechanism which will display the logic and reasoning used by the TAC*II system to make a particular decision of interest.

Finally, we should address the issue of man machine interfaces. Although it is a vital area, we felt that the primary emphasis should be placed on the actual derivations of appropriate algorithms and heuristics. In the future, graphical displays and the console interface must be investigated. It is mandatory that the system present all relevant information while suppressing irrelevant details. We do not want the tactical commander to be swamped with data, nor do we want significant information to be missed.

C. SUMMARY

TAC*II is an expert system for the tactical decision maker. It incorporates Artificial Intelligence methods, database operations, and software engineering principles, in achieving its goals. Those goals are to provide to the tactical decision maker, information about the current situation and suggestions on actions to take. The system receives preprocessed sensor inputs, and infers additional information by querying a static database of contact information. It performs target correlation by retrieving all similar contact reports from its dynamic database, and determining if any of the retrieved contact reports could aid in the identification of the current contact. When two contacts are correlated, a confidence factor is assigned according to the strength of the correlation. Finally, the production rules and patterns are searched for matches to the current situation, and the appropriate actions are displayed on the operator console.

TAC*II fills an extremely important role as an aid to the tactical decision maker. In this high pressure, high density and time critical environment, our system will perform consistently, and as "intelligently" as its expert knowledge allows. TAC*II provides a working prototype of a

very necessary tactical system from which actual systems may be developed.

APPENDIX A

SAMPLE OUTPUT FROM THE PATTERN MATCHER

The input situation is diagrammed in Figure A.1. The first six patterns encoded do not match this situation by number of platform types. Pattern 7 is the pattern shown in Figure 5.5 in Chapter 5, and has the two associated situations as described in Chapter 5. Pattern 8, shown in Figure A.2, does not have any associated situations, and therefore produces only a match vice an action. The output from the pattern matcher, given this input, is shown below.

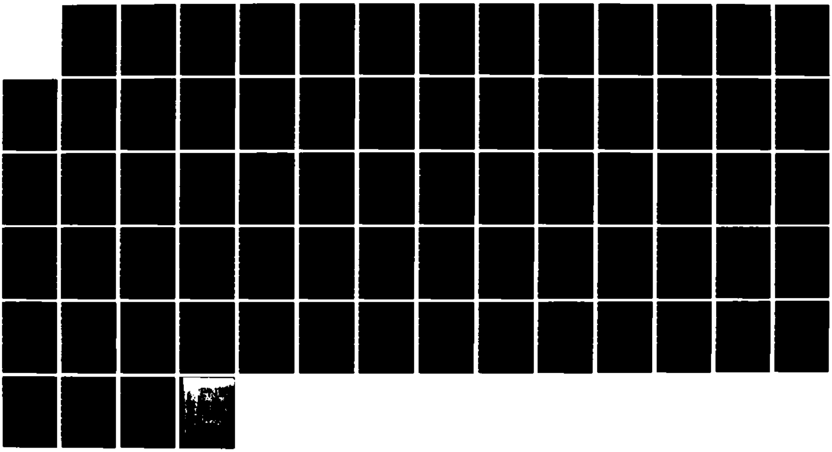
*** Terminal Session 1 ***

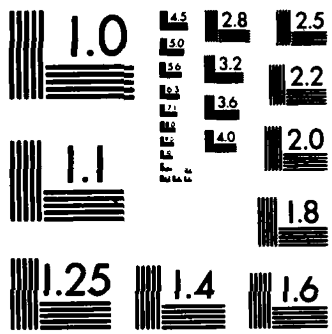
```
 PATTERNS WERE FOUND

CHECKING FOR SIGNIFICANT MATCHES

THE FOLLOWING QUESTIONS SIMULATE
QUERIES TO THE WORLD MODEL FOR SPECIFICS
 PERTAINING TO THE FIRST SITUATION

WHAT IS CONFIDENCE THAT SHIP
BEARING  100 AT RANGE    50 IS A DESTROYER? 0-100
50

WHAT IS CONFIDENCE THAT SHIP
BEARING  200 AT RANGE    75 IS A DESTROYER? 0-100
50

WHAT IS CONFIDENCE THAT SHIP
BEARING  210 AT RANGE    90 IS A CARRIER? 0-100
50

WHAT IS CONF AIR CONTACTS ARE HELOS? 0-100
```

```
50

THE FOLLOWING QUESTIONS SIMULATE
QUERIES TO THE WORLD MODEL FOR SPECIFICS
 PERTAINING TO THE SECOND SITUATION

WHAT IS CONFIDENCE THAT AIR
BEARING  290 AT RANGE    90 IS A FIGHTER? 0-100
50

WHAT IS CONFIDENCE THAT AIR
BEARING  270 AT RANGE   100 IS A FIGHTER? 0-100
80

END OF PATTERN CHECK

BEST ACTION WILL BE DISPLAYED FIRST

COME TO COURSE          280 TO CLOSE AIRCRAFT
SITUATION MATCHED WITH CONFIDENCE           80
 ON SCALE 0-100
VERY LOW TOLERANCE USED - PATTERN MATCHES EXCELLENTLY

TYPE "Y" FOR NEXT BEST ACTION
TYPE "N" FOR DONE
Y

PATTERN 8 MATCHES
NO SITUATIONS ARE PROGRAMMED YET
CONFIDENCE WILL BE 0
SITUATION MATCHED WITH CONFIDENCE            0
 ON SCALE 0-100
VERY LOW TOLERANCE USED - PATTERN MATCHES EXCELLENTLY
THIS IS THE LAST MATCHING PATTERN
PROGRAM IS TERMINATED
```

AD-A132 997 TAC * II AN EXPERT KNOWLEDGE BASED SYSTEM FOR TACTICAL DECISION MAKING(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA M J GESCHKE ET AL. JUN 83 2/2

UNCLASSIFIED F/G 17/2 NL



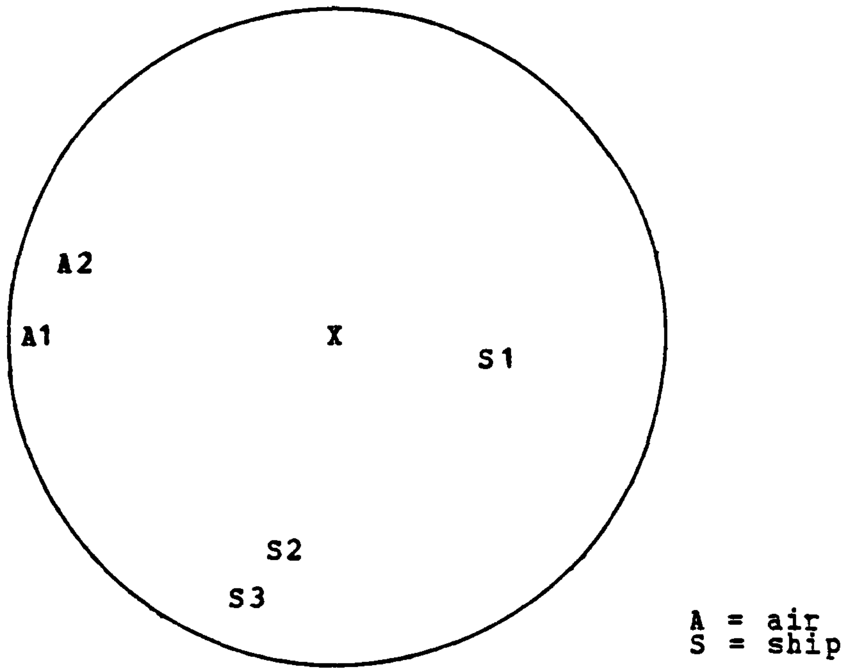


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

*** Terminal Session 2 ***

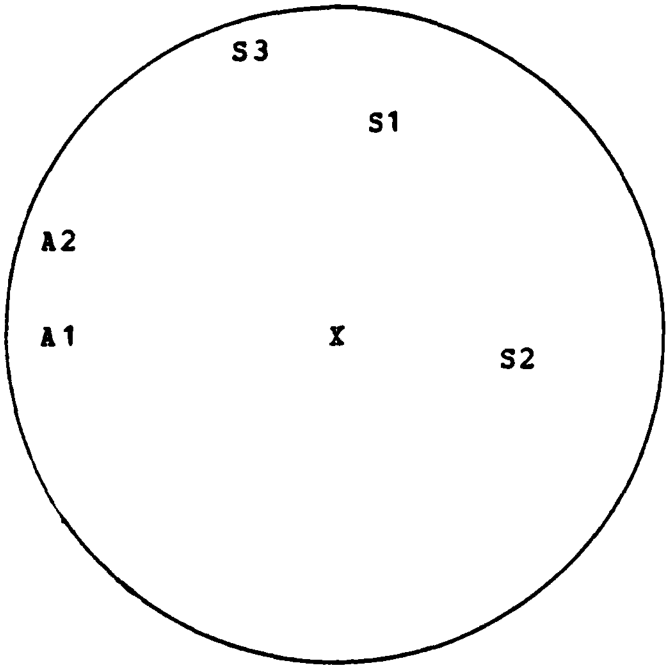
```
 PATTERNS WERE FOUND
CHECKING FOR SIGNIFICANT MATCHES

THE FOLLOWING QUESTIONS SIMULATE
QUERIES TO THE WORLD MODEL FOR SPECIFICS
 PERTAINING TO THE FIRST SITUATION

WHAT IS CONFIDENCE THAT SHIP
BEARING  100 AT RANGE    50 IS A DESTROYER? 0-100
50

WHAT IS CONFIDENCE THAT SHIP
BEARING  200 AT RANGE    75 IS A DESTROYER? 0-100
75

WHAT IS CONFIDENCE THAT SHIP
BEARING  210 AT RANGE    90 IS A CARRIER? 0-100
80

WHAT IS CONF AIR CONTACTS ARE HELOS? 0-100
50

THE FOLLOWING QUESTIONS SIMULATE
QUERIES TO THE WORLD MODEL FOR SPECIFICS
 PERTAINING TO THE SECOND SITUATION

WHAT IS CONFIDENCE THAT AIR
BEARING  290 AT RANGE    90 IS A FIGHTER? 0-100
50

WHAT IS CONFIDENCE THAT AIR
BEARING  270 AT RANGE   100 IS A FIGHTER? 0-100
25

END OF PATTERN CHECK
BEST ACTION WILL BE DISPLAYED FIRST
```

```
COME TO COURSE          335 FOR RECIPROCAL OF SHIPS
(*** SECCND SITUATION MATCHES ***)
SITUATION MATCHED WITH CONFIDENCE          73
 ON SCALE 0-100
VERY ICW TOLERANCE USED - PATTERN MATCHES EXCELLENTLY
TYPE "Y" FOR NEXT BEST ACTION
TYPE "N" FCR DONE
N
PROGRAM IS TERMINATED PER YOUR REQUEST
```



Target	Bearing	Range
A1	270	100
A2	290	90
S1	100	50
S2	200	75
S3	210	90

Figure A.1 Input Situation.



A = air
S = ship

Target	Bearing	Range
A1	270	90
A2	290	100
S1	5	70
S2	100	50
S3	350	95

Figure A.2 Pattern 8.

APPENDIX B

SAMPLE OUTPUT FROM THE ANALYSIS MODULE

These reports are the accumulation of information that was input into TAC*II for this example run. This information consists of two sections: the Combat Unit Database Information and the Sensor Reports. The system is case sensitive and the information presented here is in the case in which it was inputted into the system.

The following units were input to TAC*II As the Combat Unit Database

Class

delta III ssbn

Unit	Emitters	Weapons
delta III-1	snoop tray	ss-n-18 soviet torpedo
delta III-2	snoop tray	ss-n-18 soviet torpedo

Class

yankee ssbn

Unit	Emitters	Weapons
yankee-1	snoop tray	ss-n-16 soviet torpedo

yankee-2	snoop tray	ss-n-16 soviet torpedo

Class

papa ssgn

Unit	Emitters	Weapons
papa-1	snoop tray stop light	ss-n-15 soviet torpedo
papa-2	snoop tray stop light	ss-n-15 soviet torpedo

Class

victor III ssgn

Unit	Emitters	Weapons
victor III-1	snoop tray	ss-n-15 soviet torpedo
victor III-2	snoop tray	ss-n-15 soviet torpedo

Class

echo I ssgn

Unit	Emitters	Weapons
echo I-1	snoop tray stop light	ss-n-3 soviet torpedo soviet mine
echo I-2	snoop tray	ss-n-3

	stop light	soviet torpedo
		soviet mine

Class

kashin ddg

Unit	Emitters	Weapons
skory	head net c	sa-n-1
	big net	ss-n-2c
	peel group	76 mm
	owl screech	30 mm
	bass tilt	soviet torpedo
	don kay	
	high pole	
slavny	head net c	sa-n-1
	big net	ss-n-2c
	peel group	76 mm
	owl screech	30 mm
	bass tilt	soviet torpedo
	don kay	
	high pole	
smely	head net c	sa-n-1
	big net	ss-n-2c
	peel group	76 mm
	own screech	30 mm
	bass tilt	soviet torpedo
	don kay	
	high pole	
	own screech	
smetlivy	head net c	sa-n-1
	big net	ss-n-2c
	peel group	76 mm

	owl screech	30 mm
	bass tilt	soviet torpedo
	don kay	
	high pole	

Class

krivak II ffg

Unit	Emitters	Weapons
bodvy	head net c	ss-n-14
	eye bowl	sa-n-4
	pop group	76 mm
	owl screech	100 mm
	don kay	
	high pole	
druzhny	head net c	ss-n-14
	eye bowl	sa-n-4
	pop group	76 mm
	owl screech	100 mm
	don kay	
	high pole	
pylky	head net c	ss-n-14
	eye bowl	sa-n-4
	pop group	76 mm
	owl screech	100 mm
	don kay	
	high pole	
silny	head net c	ss-n-14
	eye bowl	sa-n-4
	pop group	76 mm
	owl screech	100 mm
	don kay	

	high pole	
retivy	head net c	ss-n-14
	eye bowl	sa-n-4
	pop group	76 mm
	owl screech	100 mm
	don kay	
	high pole	

Class

ohio ssbn

Unit	Emitters	Weapons
ohio	bqq 6	trident
	mk 98 fcs	mk 68
michigan	bqq 6	trident
	mk 98 fcs	mk 68
georgia	bqq 6	trident
	mk 98 fcs	mk 68

Class

los angeles ssn

Unit	Emitters	Weapons
los angeles		harpoon
		mk 67
		subroc
		mk 48
philadelphia		harpoon
		mk 67
		subroc

		mk 48
groton		harpoon
		mk 67
		subroc
		mk 48

Class

virginia cgn

Unit	Emitters	Weapons
virginia	sps 40b	lamps
	sps 48c	5 in 54
	sps 55	tartar
	sqs 53a	asroc
	spg 51d	
	spg 60	
	spq 9a	
texas	sps 40b	lamps
	sps 48c	5 in 54
	sps 55	tartar
	sqs 53a	asroc
	spg 51d	
	spg 60	
	spq 9a	
mississippi	sps 40b	lamps
	sps 48c	5 in 54
	sps 55	tartar
	sqs 53a	asroc
	spg 51d	
	spg 60	
	spq 9a	

arkansas	sps 40b	lamps
	sps 48c	5 in 54
	sps 55	tartar
	sqs 53a	asroc
	spg 51d	
	spg 60	
	spq 9a	

Class

belknap cg

Unit	Emitters	Weapons
belknap	sps 10	lamps
	sps 40	harpoon
	sps 43	terrier
	sps 48d	asroc
	sps 49	5 in 54
	sqs 26bx	phalanx
	sps 53a	
josephus daniels	sps 10	lamps
	sps 40	harpoon
	sps 43	terrier
	sps 48d	asroc
	sps 49	5 in 54
	sqs 26bx	phalanx
	sps 53a	
wainwright	sps 10	lamps
	sps 40	harpoon
	sps 43	terrier
	sps 48d	asroc
	sps 49	5 in 54
	sqs 26bx	phalanx

	sps 53a	
jouett	sps 10	lamps
	sps 40	harpoon
	sps 43	terrier
	sps 48d	asroc
	sps 49	5 in 54
	sqs 26bx	phalanx
	sps 53a	
horne	sps 10	lamps
	sps 40	harpoon
	sps 43	terrier
	sps 48d	asroc
	sps 49	5 in 54
	sqs 26bx	phalanx
	sps 53a	
sterett	sps 10	lamps
	sps 40	harpoon
	sps 43	terrier
	sps 48d	asroc
	sps 49	5 in 54
	sqs 26bx	phalanx
	sps 53a	

Class

<u>coontz ddg</u>

<u>Unit</u>	<u>Emitters</u>	<u>Weapons</u>
farragut	sps 10	terrier
	sps 29	harpoon
	sps 37	5 in 54
	sqs 23	asroc
	spg 53a	

	spg 55b	
luce	sps 10	terrier
	sps 29	harpoon
	sps 37	5 in 54
	sqs 23	asroc
	spg 53a	
	spg 55b	
macdonough	sps 10	terrier
	sps 29	harpoon
	sps 37	5 in 54
	sqs 23	asroc
	spg 53a	
	spg 55b	
coontz	sps 10	terrier
	sps 29	harpoon
	sps 37	5 in 54
	sqs 23	asroc
	spg 53a	
	spg 55b	
king	sps 10	terrier
	sps 29	harpoon
	sps 37	5 in 54
	sqs 23	asroc
	spg 53a	
	spg 55b	
mahan	sps 10	terrier
	sps 29	harpoon
	sps 37	5 in 54
	sqs 23	asroc
	spg 53a	
	spg 55b	

Class

iowa bb

Unit	Emitters	Weapons
iowa	sps 10	16 in
	sps 53	5 in 38
	sps 48	harpoon
		tomahawk
		standard 2-80
		mk 46
new jersey	sps 10	16 in
	sps 53	5 in 38
	sps 48	harpoon
		tomahawk
		standard 2-80
		mk 46

These are the Sensor Reports

Contact 0

Unit Name belknap

Course 000

Speed 20

DTG 150000JUN83

Reported on Sensor Surface Radar

Surface Radar Track Number 0

Contact 1

Visual Report 1

Bearing 270

Range 10

Elevation 0

Confidence Confirmed

Course 000

Speed 20

Maximum Speed -1

Unit Name farragut

Unit Confidence Confirmed

DTG 151530JUN83

Contact 2

Intelligence Report 1

Track Number -1

DTG 151600JUN83

Bearing 020

Range 200

Elevation 0

Confidence Positive

Course 115

Speed 20

Maximum Speed -1

Unit Name smely
Unit Confidence Positive
No further Units
No Class Names
No Correlations

Contact 3

ESM Report 1
ESM Bearing 025
DTG 151645JUN83
Emission dcn kay
Emission Confidence Certain

Contact 4

Surface Radar Report 1
Bearing 028
Range 50
Elevation 0
Confidence Positive
Course 215
Speed 17
Maximum Speed -1
DTG 152017JUN83

Contact 5

Sonar Report 1
Bearing 110
Range 15
Elevation 0
Course 350
Speed 27
Maximum Speed -1
Nc Unit Name
No Class Name
Platfcrm Type Surface
Platform Confidence Positive

No other Platform Types

No Alliances

DTG 151900JUN83

Contact 6

Surface Radar Report 2

DTG 152000JUN83

Bearing 100

Range 13

Elevation 0

Confidence Certain

Course 356

Speed 25

Maximum Speed -1

Contact 7

ESM Report 2

ESM Bearing 099

Emission snoop tray

Emission Confidence Certain

DTG 152001JUN83

What follows are the different reports which were generated by TAC*II in response to the above input information.

This is the initial report of own ship as induced by the Analysis Module from the information provided on startup.

No Correlation file

Analysis Report Record
Update =

Track Number = 0
DTG = 15 0JUN83
Bearing = -1
Range = -1
Elevation = -1
Position Confidence =
Confirmed
Course = 0
Speed = 20
Max Speed = 33

Identification Record
Platform Type = Surface
Platform Confidence =
Confirmed
Alliance = Friendly
Alliance Confidence =
Confirmed
Type Class = belknap cg
Class Confidence =
Confirmed
Unit Name = belknap
Unit Confidence =

Confirmed
Emitter = sps 10
Emitter Confidence =
Confirmed
Emitter = sps 40
Emitter Confidence =
Confirmed
Emitter = sps 43
Emitter Confidence =
Confirmed
Emitter = sps 48d
Emitter Confidence =
Confirmed
Emitter = sps 49
Emitter Confidence =
Confirmed
Emitter = sqs 26bx
Emitter Confidence =
Confirmed
Emitter = sps 53a
Emitter Confidence =
Confirmed
Weapon type = asw helc
Weapon name = lamps
Weapon Confidence =
Confirmed
Up Status = 100
In Weapon Range
Weapon type = ssm
Weapon name = harpoon
Weapon Confidence =
Confirmed
Up Status = 100
In Weapon Range
Weapon type = sam

Weapon name = terrier
Weapon Confidence =
Confirmed
Up Status = 100
In Weapon Range
Weapon type = asw
Weapon name = asroc
Weapon Confidence =
Confirmed
Up Status = 100
In Weapon Range
Weapon type = gun
Weapon name = 5 in 54
Weapon Confidence =
Confirmed
Up Status = 100
In Weapon Range
Weapon type = aaw
Weapon name = phalanx
Weapon Confidence =
Confirmed
Up Status = 100
In Weapon Range
Action = New Report

This is the inferred information about contact report 1 that was retrieved from the Combat Unit Database.

No Correlation file

Analysis Report Record
Update =

Track Number =   1
DTG = 151530JUN83
Bearing =   270
Range =   10
Elevation =   0
Position Confidence =
Confirmed
Course =   0
Speed =   20
Max Speed =   33

Identification Record
Platform Type = Surface
Platform Confidence =
Confirmed
Alliance = Friendly
Alliance Confidence =
Confirmed
Type Class = coontz ddg
Class Confidence =
Confirmed
Unit Name = farragut
Unit Confidence =
Confirmed
Emitter = sps 10
Emitter Confidence =

Confirmed
Emitter = sps 29
Emitter Confidence =
Confirmed
Emitter = sps 37
Emitter Confidence =
Confirmed
Emitter = sqs 23
Emitter Confidence =
Confirmed
Emitter = spg 53a
Emitter Confidence =
Confirmed
Emitter = spg 55b
Emitter Confidence =
Confirmed
Weapon type = sam
Weapon name = terrier
Weapon Confidence =
Confirmed
Up Status = 100
In Weapon Range
Weapon type = ssm
Weapon name = harpoon
Weapon Confidence =
Confirmed
Up Status = 100
In Weapon Range
Weapon type = gun
Weapon name = 5 in 54
Weapon Confidence =
Confirmed
Up Status = 100
Not In Weapon Range
Weapon type = asw

Weapon name = asroc
Weapon Confidence =
Confirmed
Up Status = 100
In Weapon Range
Action = New Report

This is the inferred information about contact report 2 that was retrieved from the Combat Unit Database.

No Correlation file

Analysis Report Record
Update =

Track Number = 2
DTG = 151600JUN83
Bearing = 20
Range = 200
Elevation = 0
Position Confidence =
Positive
Course = 115
Speed = 20
Max Speed = 35

Identification Record
Platform Type = Surface
Platform Confidence =
Positive
Alliance = Hostile

Alliance Confidence =
Positive
Type Class = kashin ddg
Class Confidence =
Positive
Unit Name = smely
Unit Confidence =
Positive
Emitter = head net c
Emitter Confidence =
Positive
Emitter = big net
Emitter Confidence =
Positive
Emitter = peel group
Emitter Confidence =
Positive
Emitter = owl screech
Emitter Confidence =
Positive
Emitter = bass tilt
Emitter Confidence =
Positive
Emitter = don kay
Emitter Confidence =
Positive
Emitter = high pole
Emitter Confidence =
Positive
Weapon type = sam
Weapon name = sa-n-1
Weapon Confidence =
Positive
Up Status = 100
Not In Weapon Range

Weapon type = ssm
Weapon name = ss-n-2c
Weapon Confidence =
Positive
Up Status = 100
Not In Weapon Range
Weapon type = gun
Weapon name = 76 mm
Weapon Confidence =
Positive
Up Status = 100
Not In Weapon Range
Weapon type = gun
Weapon name = 30 mm
Weapon Confidence =
Positive
Up Status = 100
Not In Weapon Range
Weapon type = torpedo
Weapon name = soviet torpedo
Weapon Confidence =
Positive
Up Status = 100
Not In Weapon Range
Action = New Report

This is the inferred information about contact report 3 that was retrieved from the Combat Unit Database.

No Correlation file

Analysis Report Record

Update =

Track Number = 3

DTG = 151645JUN83

Bearing = 25

Range = -1

Elevation = -1

Position Confidence =

Certain

Course = -1

Speed = 23

Max Speed = 35

Identification Record

Platform Type = Surface

Platform Confidence =

Certain

Alliance = Hostile

Alliance Confidence =

Certain

Type Class = kashin ddg

Class Confidence =

Probable

Type Class = krivak II ffg

Class Confidence =

Probable

Unit Name = bodvy

Unit Confidence =

Possible

Unit Name = druzhny

Unit Confidence =

Possible

Unit Name = pylky

Unit Confidence =

Possible

Unit Name = silny

Unit Confidence =

Possible

Unit Name = retivy

Unit Confidence =

Possible

Unit Name = skory

Unit Confidence =

Possible

Unit Name = slavny

Unit Confidence =

Possible

Unit Name = smely

Unit Confidence =

Possible

Unit Name = smetlivy

Unit Confidence =

Possible

Emitter = head net c

Emitter Confidence =

Certain

Emitter = big net

Emitter Confidence =

Probable

Emitter = peel group

Emitter Confidence =

Probable

Emitter = owl screech

Emitter Confidence =

Positive

Emitter = bass tilt

Emitter Confidence =

Probable

Emitter = don kay

```
Emitter Confidence =
Certain
Emitter = high pole
Emitter Confidence =
Certain
Emitter = own screech
Emitter Confidence =
Possible
Emitter = eye bowl
Emitter Confidence =
Probable
Emitter = pop group
Emitter Confidence =
Probable
Weapon type = sam
Weapon name = sa-n-1
Weapon Confidence =
Probable
Up Status =          100
In Weapon Range
Weapon type = ssm
Weapon name = ss-n-2c
Weapon Confidence =
Probable
Up Status =          100
In Weapon Range
Weapon type = gun
Weapon name = 76 mm
Weapon Confidence =
Certain
Up Status =          100
In Weapon Range
Weapon type = gun
Weapon name = 30 mm
Weapon Confidence =
```

Probable
Up Status =   100
In Weapon Range
Weapon type = torpedo
Weapon name = soviet torpedo
Weapon Confidence =
Probable
Up Status =   100
In Weapon Range
Weapon type = ssm
Weapon name = ss-n-14
Weapon Confidence =
Probable
Up Status =   100
In Weapon Range
Weapon type = sam
Weapon name = sa-n-4
Weapon Confidence =
Probable
Up Status =   100
In Weapon Range
Weapon type = gun
Weapon name = 100 mm
Weapon Confidence =
Probable
Up Status =   100
In Weapon Range
Action = New Report

This report is the result of the correlation made by the Analysis Module between contact reports 2 and 3.

Analysis Report Record
Update =

Track Number = 2
DTG = 151600JUN83
Bearing = 20
Range = 200
Elevation = 0
Position Confidence =
Positive
Course = 115
Speed = 20
Max Speed = 35

Identification Record
Platform Type = Surface
Platform Confidence =
Certain
Alliance = Hostile
Alliance Confidence =
Certain
Type Class = krivak II ffg
Class Confidence =
Plausible
Type Class = kashin ddg
Class Confidence =
Positive
Unit Name = smetlivy
Unit Confidence =
Possible
Unit Name = slavny
Unit Confidence =
Possible
Unit Name = skory

Unit Confidence =
Possible
Unit Name = retivy
Unit Confidence =
Possible
Unit Name = silny
Unit Confidence =
Possible
Unit Name = pylky
Unit Confidence =
Possible
Unit Name = druzhny
Unit Confidence =
Possible
Unit Name = bodvy
Unit Confidence =
Possible
Unit Name = smely
Unit Confidence =
Positive
Emitter = pop group
Emitter Confidence =
Plausible
Emitter = eye bowl
Emitter Confidence =
Plausible
Emitter = owl screech
Emitter Confidence =
Sure
Emitter = head net c
Emitter Confidence =
Certain
Emitter = big net
Emitter Confidence =
Positive

Emitter = peel group
Emitter Confidence =
Positive
Emitter = own screech
Emitter Confidence =
Positive
Emitter = bass tilt
Emitter Confidence =
Positive
Emitter = don kay
Emitter Confidence =
Certain
Emitter = high pole
Emitter Confidence =
Certain
Weapon type = gun
Weapon name = 100 mm
Weapon Confidence =
Plausible
Up Status = 100
Not In Weapon Range
Weapon type = sam
Weapon name = sa-n-4
Weapon Confidence =
Plausible
Up Status = 100
Not In Weapon Range
Weapon type = ssm
Weapon name = ss-n-14
Weapon Confidence =
Plausible
Up Status = 100
Not In Weapon Range
Weapon type = sam
Weapon name = sa-n-1

Weapon Confidence =
Positive
Up Status = 100
Not In Weapon Range
Weapon type = ssm
Weapon name = ss-n-2c
Weapon Confidence =
Positive
Up Status = 100
Not In Weapon Range
Weapon type = gun
Weapon name = 76 mm
Weapon Confidence =
Certain
Up Status = 100
Not In Weapon Range
Weapon type = gun
Weapon name = 30 mm
Weapon Confidence =
Positive
Up Status = 100
Not In Weapon Range
Weapon type = torpedo
Weapon name = soviet torpedo
Weapon Confidence =
Positive
Up Status = 100
Not In Weapon Range
Correlated Track Number = 3
Correlation Confidence =
Positive
Action = New Report

Analysis Report Record

Update =

Track Number = 3
DTG = 151645JUN83
Bearing = 25
Range = -1
Elevation = -1
Position Confidence =
Certain
Course = -1
Speed = 23
Max Speed = 35

Identification Record
Platform Type = Surface
Platform Confidence =
Certain
Alliance = Hostile
Alliance Confidence =
Certain
Type Class = kashin ddg
Class Confidence =
Confident
Type Class = krivak II ffg
Class Confidence =
Probable
Unit Name = bodvy
Unit Confidence =
Possible
Unit Name = druzhny
Unit Confidence =
Possible
Unit Name = pylky
Unit Confidence =
Possible

Unit Name = silny
Unit Confidence =
Possible
Unit Name = retivy
Unit Confidence =
Possible
Unit Name = skory
Unit Confidence =
Possible
Unit Name = slavny
Unit Confidence =
Possible
Unit Name = smely
Unit Confidence =
Possible
Unit Name = smetlivy
Unit Confidence =
Possible
Emitter = head net c
Emitter Confidence =
Certain
Emitter = big net
Emitter Confidence =
Confident
Emitter = peel group
Emitter Confidence =
Confident
Emitter = owl screech
Emitter Confidence =
Positive
Emitter = bass tilt
Emitter Confidence =
Confident
Emitter = don kay
Emitter Confidence =

Certain
Emitter = high pole
Emitter Confidence =
Certain
Emitter = own screech
Emitter Confidence =
Possible
Emitter = eye bowl
Emitter Confidence =
Probable
Emitter = pop group
Emitter Confidence =
Probable
Weapon type = sam
Weapon name = sa-n-1
Weapon Confidence =
Confident
Up Status = 100
In Weapon Range
Weapon type = ssm
Weapon name = ss-n-2c
Weapon Confidence =
Confident
Up Status = 100
In Weapon Range
Weapon type = gun
Weapon name = 76 mm
Weapon Confidence =
Certain
Up Status = 100
In Weapon Range
Weapon type = gun
Weapon name = 30 mm
Weapon Confidence =
Confident

Up Status = 100
In Weapon Range
Weapon type = torpedo
Weapon name = soviet torpedo
Weapon Confidence =
Confident
Up Status = 100
In Weapon Range
Weapon type = ssm
Weapon name = ss-n-14
Weapon Confidence =
Probable
Up Status = 100
In Weapon Range
Weapon type = sam
Weapon name = sa-n-4
Weapon Confidence =
Probable
Up Status = 100
In Weapon Range
Weapon type = gun
Weapon name = 100 mm
Weapon Confidence =
Probable
Up Status = 100
In Weapon Range
Correlated Track Number = 2
Correlation Confidence =
Positive
Action = New Report

This is the inferred information about contact report 4 that was retrieved from the Combat Unit Database.

No Alliance file
No class file
No Emitter file
No Unit file
No Weapon file
No Correlation file

Analysis Report Record
Update =

Track Number = 4
DTG = 152017JUN83
Bearing = 28
Range = 50
Elevation = 0
Position Confidence =
Positive
Course = 215
Speed = 17
Max Speed = -1

Identification Record
Platform Type = Surface
Platform Confidence =
Positive
Action = New Report

This report is the result of the correlation made by the Analysis Module between contact report 4 and reports 3 and 4.

Analysis Report Record
Update =

Track Number = 2
DTG = 151600JUN83
Bearing = 20
Range = 200
Elevation = 0
Position Confidence =
Positive
Course = 115
Speed = 20
Max Speed = 35

Identification Record
Platform Type = Surface
Platform Confidence =
Certain
Alliance = Hostile
Alliance Confidence =
Certain
Type Class = krivak II ffg
Class Confidence =
Plausible
Type Class = kashin ddg
Class Confidence =
Positive
Unit Name = smetlivy
Unit Confidence =
Possible

Unit Name = slavny

Unit Confidence =

Possible

Unit Name = skory

Unit Confidence =

Possible

Unit Name = retivy

Unit Confidence =

Possible

Unit Name = silny

Unit Confidence =

Possible

Unit Name = pylky

Unit Confidence =

Possible

Unit Name = druzhny

Unit Confidence =

Possible

Unit Name = bodvy

Unit Confidence =

Possible

Unit Name = smely

Unit Confidence =

Positive

Emitter = pcp group

Emitter Confidence =

Plausible

Emitter = eye bowl

Emitter Confidence =

Plausible

Emitter = owl screech

Emitter Confidence =

Sure

Emitter = head net c

Emitter Confidence =

Certain
Emitter = big net
Emitter Confidence =
Positive
Emitter = peel group
Emitter Confidence =
Positive
Emitter = own screech
Emitter Confidence =
Positive
Emitter = bass tilt
Emitter Confidence =
Positive
Emitter = don kay
Emitter Confidence =
Certain
Emitter = high pole
Emitter Confidence =
Certain
Weapon type = gun
Weapon name = 100 mm
Weapon Confidence =
Plausible
Up Status = 100
Not In Weapon Range
Weapon type = sam
Weapon name = sa-n-4
Weapon Confidence =
Plausible
Up Status = 100
Not In Weapon Range
Weapon type = ssm
Weapon name = ss-n-14
Weapon Confidence =
Plausible

Up Status = 100
Not In Weapon Range
Weapon type = sam
Weapon name = sa-n-1
Weapon Confidence =
Positive
Up Status = 100
Not In Weapon Range
Weapon type = ssm
Weapon name = ss-n-2c
Weapon Confidence =
Positive
Up Status = 100
Not In Weapon Range
Weapon type = gun
Weapon name = 76 mm
Weapon Confidence =
Certain
Up Status = 100
Not In Weapon Range
Weapon type = gun
Weapon name = 30 mm
Weapon Confidence =
Positive
Up Status = 100
Not In Weapon Range
Weapon type = torpedo
Weapon name = soviet torpedo
Weapon Confidence =
Positive
Up Status = 100
Not In Weapon Range
Correlated Track Number = 4
Correlation Confidence =
Certain

Correlated Track Number = 3

Correlation Confidence =

Positive

Action = New Report

Analysis Report Record

Update =

Track Number = 3

DTG = 151645JUN83

Bearing = 25

Range = -1

Elevation = -1

Position Confidence =

Certain

Course = -1

Speed = 23

Max Speed = 35

Identification Record

Platform Type = Surface

Platform Confidence =

Certain

Alliance = Hostile

Alliance Confidence =

Certain

Type Class = kashin ddg

Class Confidence =

Sure

Type Class = krivak II ffg

Class Confidence =

Probable

Unit Name = bodvy

Unit Confidence =

Possible
Unit Name = druzhny
Unit Confidence =
Possible
Unit Name = pylky
Unit Confidence =
Possible
Unit Name = silny
Unit Confidence =
Possible
Unit Name = retivy
Unit Confidence =
Possible
Unit Name = skory
Unit Confidence =
Possible
Unit Name = slavny
Unit Confidence =
Possible
Unit Name = smely
Unit Confidence =
Possible
Unit Name = smetlivy
Unit Confidence =
Possible
Emitter = head net c
Emitter Confidence =
Certain
Emitter = big net
Emitter Confidence =
Sure
Emitter = peel group
Emitter Confidence =
Sure
Emitter = owl screech

Emitter Confidence =
Positive
Emitter = bass tilt
Emitter Confidence =
Sure
Emitter = don kay
Emitter Confidence =
Certain
Emitter = high pole
Emitter Confidence =
Certain
Emitter = own screech
Emitter Confidence =
Possible
Emitter = eye bowl
Emitter Confidence =
Probable
Emitter = pop group
Emitter Confidence =
Probable
Weapon type = sam
Weapon name = sa-n-1
Weapon Confidence =
Sure
Up Status = 100
In Weapon Range
Weapon type = ssm
Weapon name = ss-n-2c
Weapon Confidence =
Sure
Up Status = 100
In Weapon Range
Weapon type = gun
Weapon name = 76 mm
Weapon Confidence =

Certain
Up Status = 100
In Weapon Range
Weapon type = gun
Weapon name = 30 mm
Weapcn Ccnfidence =
Sure
Up Status = 100
In Weapon Range
Weapon type = torpedc
Weapon name = soviet torpedo
Weapcn Ccnfidence =
Sure
Up Status = 100
In Weapon Range
Weapcn type = ssm
Weapon name = ss-n-14
Weapcn Ccnfidence =
Probable
Up Status = 100
In Weapon Range
Weapcn type = sam
Weapon name = sa-n-4
Weapcn Ccnfidence =
Probable
Up Status = 100
In Weapon Range
Weapon type = gun
Weapcn name = 100 mm
Weapcn Ccnfidence =
Probable
Up Status = 100
In Weapon Range
Correlated Track Nurber = 4
Correlaticn Confidence =

Positive
Correlated Track Number = 2
Correlation Confidence =
Positive
Action = New Report

Analysis Report Record
Update =

Track Number = 4
DTG = 152017JUN83
Bearing = 28
Range = 50
Elevation = 0
Position Confidence =
Positive
Course = 215
Speed = 17
Max Speed = 35

Identification Record
Platform Type = Surface
Platform Confidence =
Certain
Alliance = Hostile
Alliance Confidence =
Certain
Type Class = kashin ddg
Class Confidence =
Positive
Type Class = krivak II ffg
Class Confidence =
Possible
Unit Name = smely

Unit Confidence =
Positive
Unit Name = bodvy
Unit Confidence =
Possible
Unit Name = druzhny
Unit Confidence =
Possible
Unit Name = pylky
Unit Confidence =
Possible
Unit Name = silny
Unit Confidence =
Possible
Unit Name = retivy
Unit Confidence =
Possible
Unit Name = skory
Unit Confidence =
Possible
Unit Name = slavny
Unit Confidence =
Possible
Unit Name = smetlivy
Unit Confidence =
Possible
Emitter = high pole
Emitter Confidence =
Certain
Emitter = don kay
Emitter Confidence =
Certain
Emitter = bass tilt
Emitter Confidence =
Positive

Emitter = own screech
Emitter Confidence =
Positive
Emitter = peel group
Emitter Confidence =
Positive
Emitter = big net
Emitter Confidence =
Positive
Emitter = head net c
Emitter Confidence =
Certain
Emitter = owl screech
Emitter Confidence =
Sure
Emitter = eye bowl
Emitter Confidence =
Possible
Emitter = pop group
Emitter Confidence =
Possible
Weapon type = torpedo
Weapon name = soviet torpedo
Weapon Confidence =
Positive
Up Status =   100
Not In Weapon Range
Weapon type = gun
Weapon name = 30 mm
Weapon Confidence =
Positive
Up Status =   100
Not In Weapon Range
Weapon type = gun
Weapon name = 76 mm

Weapon Confidence =
Certain
Up Status = 100
Not In Weapon Range
Weapon type = ssm
Weapon name = ss-n-2c
Weapon Confidence =
Positive
Up Status = 100
Not In Weapon Range
Weapon type = sam
Weapon name = sa-n-1
Weapon Confidence =
Positive
Up Status = 100
In Weapon Range
Weapon type = ssm
Weapon name = ss-n-14
Weapon Confidence =
Possible
Up Status = 100
In Weapon Range
Weapon type = sam
Weapon name = sa-n-4
Weapon Confidence =
Possible
Up Status = 100
Not In Weapon Range
Weapon type = gun
Weapon name = 100 mm
Weapon Confidence =
Possible
Up Status = 100
Not In Weapon Range
Correlated Track Number = 3

Correlation Confidence =

Positive

Correlated Track Number = 2

Correlation Confidence =

Certain

Action = New Report

This is the inferred information about contact report 5 that was retrieved from the Combat Unit Database.

No Alliance file

No class file

No Emitter file

No Unit file

No Weapon file

No Correlation file

Analysis Report Record

Update =

Track Number = 5

DTG = 151900JUN83

Bearing = 110

Range = 15

Elevation = 0

Position Confidence =

Positive

Course = 350

Speed = 27

Max Speed = -1

Identification Record
Platform Type = Surface
Platform Confidence =
Positive
Action = New Report

This is the inferred information about contact report 6 that was retrieved from the Combat Unit Database.

No Alliance file
No class file
No Emitter file
No Unit file
No Weapon file
No Correlation file

Analysis Report Record
Update =

Track Number = 6
DTG = 152000JUN83
Bearing = 100
Range = 13
Elevation = 0
Position Confidence =
Certain
Course = 356
Speed = 25
Max Speed = -1

Identification Record

Platform Type = Surface
Platform Confidence =
Certain
Action = New Report

This report is the result of the correlation made by the Analysis Module between contact reports 5 and 6.

No Alliance file
No class file
No Emitter file
No Unit file
No Weapon file

Analysis Report Record
Update =

Track Number = 5
DTG = 151900JUN83
Bearing = 110
Range = 15
Elevation = 0
Position Confidence =
Positive
Course = 350
Speed = 27
Max Speed = -1

Identification Record
Platform Type = Surface
Platform Confidence =

Positive
Correlated Track Number = 6
Correlation Confidence =
Sure
Action = New Report

Analysis Report Record
Update =

Track Number = 6
DTG = 152000JUN83
Bearing = 100
Range = 13
Elevation = 0
Position Confidence =
Certain
Course = 356
Speed = 25
Max Speed = -1

Identification Record
Platform Type = Surface
Platform Confidence =
Certain
Correlated Track Number = 5
Correlation Confidence =
Sure
Action = New Report

This is the inferred information about contact report 7 that was retrieved from the Combat Unit Database.

No Correlation file

Analysis Report Record
Update =

Track Number = 7
DTG = 152001JUN83
Bearing = 99
Range = -1
Elevation = -1
Position Confidence =
Certain
Course = -1
Speed = 21
Max Speed = 31

Identification Record
Platform Type = Submarine
Platform Confidence =
Certain
Alliance = Hostile
Alliance Confidence =
Certain
Type Class = delta III ssbn
Class Confidence =
Possible
Type Class = yankee ssbn
Class Confidence =
Possible
Type Class = papa ssgn
Class Confidence =
Possible
Type Class = victor III ssgn

Class Confidence =
Possible
Type Class = echo I ssgn
Class Confidence =
Possible
Unit Name = echo I-1
Unit Confidence =
Possible
Unit Name = victor III-1
Unit Confidence =
Possible
Unit Name = victor III-2
Unit Confidence =
Possible
Unit Name = papa-1
Unit Confidence =
Possible
Unit Name = yankee-1
Unit Confidence =
Possible
Unit Name = yankee-2
Unit Confidence =
Possible
Unit Name = delta III-1
Unit Confidence =
Possible
Unit Name = delta III-2
Unit Confidence =
Possible
Emitter = snoop tray
Emitter Confidence =
Certain
Emitter = stop light
Emitter Confidence =
Possible

Weapon type = ssm
Weapon name = ss-n-18
Weapon Confidence =
Possible
Up Status =   100
In Weapon Range
Weapon type = torpedo
Weapon name = soviet torpedo
Weapon Confidence =
Certain
Up Status =   100
In Weapon Range
Weapon type = ssm
Weapon name = ss-n-16
Weapon Confidence =
Possible
Up Status =   100
In Weapon Range
Weapon type = ssm
Weapon name = ss-n-15
Weapon Confidence =
Plausible
Up Status =   100
In Weapon Range
Weapon type = ssm
Weapon name = ss-n-3
Weapon Confidence =
Possible
Up Status =   100
In Weapon Range
Weapon type = mine
Weapon name = soviet mine
Weapon Confidence =
Possible
Up Status =   100

In Weapon Range
Action = New Report

This report is the result of the correlation made by the Analysis Module between contact report 7 and reports 5 and 6.

Analysis Report Record
Update =

Track Number = 6
DTG = 152000JUN83
Bearing = 100
Range = 13
Elevation = 0
Position Confidence =
Certain
Course = 356
Speed = 25
Max Speed = 31

Identification Record
Platform Type = Submarine
Platform Confidence =
Sure
Platform Type = Surface
Platform Confidence =
Certain
Alliance = Hostile
Alliance Confidence =
Sure
Type Class = echo I ssgn

Class Confidence =
Possible
Type Class = victor III ssgn
Class Confidence =
Possible
Type Class = papa ssgn
Class Confidence =
Possible
Type Class = yankee ssbn
Class Confidence =
Possible
Type Class = delta III ssbn
Class Confidence =
Possible
Unit Name = delta III-2
Unit Confidence =
Possible
Unit Name = delta III-1
Unit Confidence =
Possible
Unit Name = yankee-2
Unit Confidence =
Possible
Unit Name = yankee-1
Unit Confidence =
Possible
Unit Name = papa-1
Unit Confidence =
Possible
Unit Name = victor III-2
Unit Confidence =
Possible
Unit Name = victor III-1
Unit Confidence =
Possible

Unit Name = echo I-1

Unit Confidence =

Possible

Emitter = stop light

Emitter Confidence =

Possible

Emitter = snoop tray

Emitter Confidence =

Sure

Weapon type = mine

Weapon name = soviet mine

Weapon Confidence =

Possible

Up Status = 100

Not In Weapon Range

Weapon type = ssm

Weapon name = ss-n-3

Weapon Confidence =

Possible

Up Status = 100

In Weapon Range

Weapon type = ssm

Weapon name = ss-n-15

Weapon Confidence =

Possible

Up Status = 100

In Weapon Range

Weapon type = ssm

Weapon name = ss-n-16

Weapon Confidence =

Possible

Up Status = 100

In Weapon Range

Weapon type = torpedo

Weapon name = soviet torpedo

Weapon Confidence =
Sure
Up Status = 100
Not In Weapon Range
Weapon type = ssm
Weapon name = ss-n-18
Weapon Confidence =
Possible
Up Status = 100
In Weapon Range
Correlated Track Number = 7
Correlation Confidence =
Sure
Correlated Track Number = 5
Correlation Confidence =
Sure
Action = New Report

Analysis Report Record
Update =

Track Number = 5
DTG = 151900JUN83
Bearing = 110
Range = 15
Elevation = 0
Position Confidence =
Positive
Course = 350
Speed = 27
Max Speed = 31

Identification Record
Platform Type = Submarine

Platform Confidence =
Certain
Platform Type = Surface
Platform Confidence =
Certain
Alliance = Hostile
Alliance Confidence =
Certain
Type Class = echo I ssgn
Class Confidence =
Possible
Type Class = victor III ssgn
Class Confidence =
Possible
Type Class = papa ssgn
Class Confidence =
Possible
Type Class = yankee ssbn
Class Confidence =
Possible
Type Class = delta III ssbn
Class Confidence =
Possible
Unit Name = delta III-2
Unit Confidence =
Possible
Unit Name = delta III-1
Unit Confidence =
Possible
Unit Name = yankee-2
Unit Confidence =
Possible
Unit Name = yankee-1
Unit Confidence =
Possible

Unit Name = papa-1
Unit Confidence =
Possible
Unit Name = victor III-2
Unit Confidence =
Possible
Unit Name = victor III-1
Unit Confidence =
Possible
Unit Name = echo I-1
Unit Confidence =
Possible
Emitter = stop light
Emitter Confidence =
Possible
Emitter = snoop tray
Emitter Confidence =
Certain
Weapon type = mine
Weapon name = soviet mine
Weapon Confidence =
Possible
Up Status = 100
Not In Weapon Range
Weapon type = ssm
Weapon name = ss-n-3
Weapon Confidence =
Possible
Up Status = 100
In Weapon Range
Weapon type = ssm
Weapon name = ss-n-15
Weapon Confidence =
Possible
Up Status = 100

In Weapon Range
Weapon type = ssm
Weapon name = ss-n-16
Weapon Confidence =
Possible
Up Status =   100
In Weapon Range
Weapon type = torpedo
Weapon name = soviet torpedo
Weapon Confidence =
Certain
Up Status =   100
Not In Weapon Range
Weapon type = ssm
Weapon name = ss-n-18
Weapon Confidence =
Possible
Up Status =   100
In Weapon Range
Correlated Track Number =   7
Correlation Confidence =
Certain
Correlated Track Number =   6
Correlation Confidence =
Sure
Action = New Report

Analysis Report Record
Update =

Track Number =   7
DTG = 152001JUN83
Bearing =   99
Range =   -1

Elevation = -1

Position Confidence =

Certain

Course = -1

Speed = 21

Max Speed = 31

Identification Record

Platform Type = Surface

Platform Confidence =

Certain

Platform Type = Submarine

Platform Confidence =

Certain

Alliance = Hostile

Alliance Confidence =

Certain

Type Class = delta III ssbn

Class Confidence =

Possible

Type Class = yankee ssbn

Class Confidence =

Possible

Type Class = papa ssgn

Class Confidence =

Possible

Type Class = victor III ssgn

Class Confidence =

Possible

Type Class = echo I ssgn

Class Confidence =

Possible

Unit Name = echo I-1

Unit Confidence =

Possible

Unit Name = victor III-1
Unit Confidence =
Possible
Unit Name = victor III-2
Unit Confidence =
Possible
Unit Name = papa-1
Unit Confidence =
Possible
Unit Name = yankee-1
Unit Confidence =
Possible
Unit Name = yankee-2
Unit Confidence =
Possible
Unit Name = delta III-1
Unit Confidence =
Possible
Unit Name = delta III-2
Unit Confidence =
Possible
Emitter = snoop tray
Emitter Confidence =
Certain
Emitter = stop light
Emitter Confidence =
Possible
Weapon type = ssm
Weapon name = ss-n-18
Weapon Confidence =
Possible
Up Status = 100
In Weapon Range
Weapon type = torpedo
Weapon name = soviet torpedo

Weapon Confidence =
Certain
Up Status = 100
In Weapon Range
Weapon type = ssm
Weapon name = ss-n-16
Weapon Confidence =
Possible
Up Status = 100
In Weapon Range
Weapon type = ssm
Weapon name = ss-n-15
Weapon Confidence =
Plausible
Up Status = 100
In Weapon Range
Weapon type = ssm
Weapon name = ss-n-3
Weapon Confidence =
Possible
Up Status = 100
In Weapon Range
Weapon type = mine
Weapon name = soviet mine
Weapon Confidence =
Possible
Up Status = 100
In Weapon Range
Correlated Track Number = 5
Correlation Confidence =
Certain
Correlated Track Number = 6
Correlation Confidence =
Sure
Action = New Report

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